# NRC BANANA

## ANNUAL REPORT
## वार्षिक प्रतिवेदन
## 2010 - 2011


NATIONAL RESEARCH CENTRE FOR BANANA
राष्ट्रीय केला अनुसंधान केंद्र

# वार्षिक प्रतिवेदन २०१० - '११

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## राष्ट्रीय केला अनुसंधान केंद्र

(भारतीय कृषि अनुसंधान परिषद)

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# PREFACE

Banana and plantain ranks next to rice, wheat and maize in terms of its importance as a food crop. In addition to being a major cash crop around the world, more than 85% of bananas are grown for local consumption in tropical and subtropical regions. Banana fruits can be cooked, roasted (plantains) or eaten raw (yellow and Cavendish banana). Bananas have contributed as the staple diets of numerous peoples in the tropics and subtropics. Current global production of more than 100 million tons is based on large-scale vegetative propagation of narrow genetic base. These clones are particularly susceptible to diseases, pests, and current changes in climate. The challenge for banana improvement is to produce resistant and sterile hybrids to meet the consumer expectations with required breeding strategy.

To over come the recalcitrant nature of the seeds and germination and regeneration, the improvement group has developed strategies for seed germination and regeneration of the hybrid embryos. In addition mass multiplication technologies have been fine tuned with low cost substitutes to reduce the cost of the micro propagation plants. Further, research activities are initiated to identify the genes responsible for major biotic stresses like nematodes, wilt and leaf spot diseases.

Production technologies have been standardized for optimizing the population with fertigation technologies so as to increase the input and water use productivity. Also micro-nutrients requirement with sulphur has been standardized for increasing the productivity under high pH soils and for correcting the micro nutrients deficiency. Fertilizer response equations have been standardized for maximizing the use efficiency of fertilizers so as to reduce the cost of production.

With an objective to develop eco-friendly integrated pests, nematodes and diseases management strategies, effective bio control agents have been identified for the control of major nematodes, corm and stem weevils, *Fusarium* wilt pathogen and leaf spot disease. Effective semio-chemicals have been identified for monitoring and control of corm and stem weevils. The casual organism for leaf spot disease has been identified as *Mycosphaerella eumusae*. Technologies have been standardized to detect episomal virus of BSMysV and BBT viruses.

Various banana value added products technologies have been disseminated and transferred to the entrepreneurs and various stake holders by organizing trainings and contact programmes. Also, a global conference was organized on climate change on banana and many collaborative and linkages with national and international agencies have been initiated.

I would like express my sincere gratitude to Dr. S. Ayyappan, Secretary,DARE and Director General, ICAR for his valuable guidance and Dr. H.P.Singh, Dy. Director General (Hort.), ICAR for his constant inspiration and encouragement. I also compliment the Chairman and members of the publication committee of the NRC Banana for their input in bringing out this document in time.

7th July, 2011
Tiruchirapalli

**(M.M. Mustaffa)**
Director

# 2 कार्यकारी सारांश

## फसल सुधार

राष्ट्रीय केला अनुसंधान केन्द्र (NRCB) मूसा जीन बैंक आगे त्रिपुरा से तीन एकसेशिन्स और मू. वस्त्र, मू. बोमन, मू. बल्बिसिअना प्रकार तानी बेल्जियम से सहित 28 आईटीसी एकसेशिन्स जोड़कर मजबूत कियागया था। 90 एकसेशिन्स वर्गीकरण सलाहकार समूह द्वारा मूसा के लिए न्यूनतम फोटो डिस्क्रिप्टर का उपयोग करने के लिए एक डेटाबेस बनाया गया था। सात बिहार एकसेशिन्स 121 वर्णों के लिए INIBAP / IPGRI विवरणक का उपयोग विशेषता थे । खेतों के मूल्यांकन cv के पुनर्जीवित पौधों ईसीएस. नेंद्रण पता चला है कि ईसीएस व्युत्पन्नपौधों सक्कर (एक गोली या बेंत जो एक पेड़ या झाड़ी के आधार पर एक कली से या अपनी जड़ों से बढ़ता है ) और गोली मार टिप व्युत्पन्न टिशू कल्चर पौधों जैसे पारंपरिक व्युत्पन्न पौधों कीतुलना में बेहतर प्रदर्शन कर रहे हैं । उनके पोषण संबंधी मानकों पर आधारित वाणिज्यिक कलटिवर (वांछनीय विशेषताओं है कि प्रचार के द्वारा बनाए रखा जा सकता है के लिए चयनित पौधों की संयंत्र या समूह) के मूल्यांकन का संकेत दिया है कि, पचानाढन और नेंद्रण, उद्यम किस्म के बाद सभी खनिजों और कैरोटीनॉयड के लिए सम्मान के साथ अत्यधिक पौष्टिक होते हैं।

एक डेटाबेस के लिए संकर बीज उत्पादन और उनके उत्थान के लिए सबसे अच्छा मौसम कोसमझने के लिए बनाया गया है । हालांकि बीज सेट फ्लशिस में साल भर में मनाया गया, बीज अंकुरण और संयंत्रपुनर्जनन केवल नवंबर - दिसम्बर महीने के दौरान सेट बीज से प्राप्त किया जा सकता है।

मूसा एसपीपी के संग्रहीत बीज की पुनर्जनन 24°C पर 12 महीने के बाद 48 घंटे के लिए GA3 भिगोने द्वारा (21.3%) प्राप्त किया। इसी तरह, जिब्बेरेल्लिक एसिड में हौसले से काटा संकर बीज का 0.2 मिलीग्राम / लीटर भिगोने 72 घंटों के लिए BAP और IAA उपचार की तुलना में 80.48% के उच्चतम बीज अंकुरण का प्रदर्शन किया । Cv ग्रैंड नैन के भ्रूण घट्टा के प्रसार, एमएस 0.01- 0.05% सक्रिय लकड़ी का कोयला केसाथ पूरक मध्यम में हासिल की थी। Cv ग्रैंड नैन के भ्रूण घट्टा के प्रसार, एमएस मध्यम के साथ पूरक में 0.01- 0.05 % सक्रिय लकड़ी के कोयला से हासिल की थी । मू. अक्कुमिनाटा एसएसपी (एए) बर्मनिका के परिपक्व और अपरिपक्व भ्रूण से युवा पौधों के उत्थान के लिए एकसरल और कुशल प्रोटोकॉल विकसित किया गया था । और इस परंपरागत दृष्टिकोण के माध्यम से मूसा सुधार कार्यक्रम को सुविधा होगी।

रस्थाली के उत्परिवर्तित और गैर उत्परिवर्तित पौधों पर, आण्विक मार्कर अध्ययन से, उत्परिवर्तित पौधों में उच्च बहुरूपता दिखाया गया। ISSR विश्लेषण भी स्पष्ट रूप से उत्परिवर्तित पौधों को गैर उत्परिवर्तित रस्थाली पौधों से प्रतिष्ठितप्रदर्शन किया । सिगाटोका प्रतिरोधी *मूसा अक्कुमिनाटा* cv मनोरंजिथं के लिए एक SSH 850 क्लोन मिलकर पुस्तकालय बनाया गया है, जो मैकोस्फरेल्ला यूमुसे के साथ चुनौती दी गई थी । 850 क्लोन की कुल में से, जीन की 0.5% रक्षा जीन के साथ मारा गया। ख्यात *प्रत्यर्लेकस काफ्फिए* प्रतिरोधी कलटिवर के SSH पुस्तकालयसे प्राप्त जीन की अभिव्य-क्ति की रूपरेखा से पता चला है कि रक्षा जीन दोनों, अतिसंवेदनशील और प्रतिरोधी फसल में विनियमित रहे हैं, लेकिन, प्रतिलेख स्तर उच्च गया था और अतिसंवेदनशील कलटिवर से पहले विनियमित । RGA विशिष्ट प्राइमरों की अभिव्यक्ति, C6RGA सिर्फ प्रतिरोधी कलटिवर में ही व्यक्त किया गया था और अतिसंवेदनशील कलटिवर में व्यक्त नहीं था।

## फसल उत्पादन

व्यापक रिक्ति(2.1 एक्स 2.4m) और 300:400 ग्राम नाइट्रोजन और पोटेशियम की आवेदन के साथ, उद्यम ने सबसे कम फल अम्लता (0.45%) और उच्चतम लुगदी : छील अनुपात (6.69) दर्ज की । इसके अलावा, व्यापक रिक्ति पौधों ने करीब रिक्ति पौधों जैसे शीघ्र फूल खिलने का प्रदर्शन की। व्यापक रिक्ति में रूट गाँठ निमेटोड जनसंख्या कम थी (मिट्टी का 32.3/250g), निकटतम रिक्ति की तुलना में । गड्ढे प्रति तीन सक्कर के साथ उद्यम केले की 3.6X3.6m दूरी पर रोपण लंबी पौधों (3.91m) दर्ज कीजहां के रूप में, 2.1 एक्स 2.4m रिक्ति पर गड्ढे प्रति एकसंयंत्र में कम से कम पौधों दर्ज (3.65 मीटर) BSV और BBMV संक्रमित पूवन ऑर्गेनिक्स के प्रभाव पर अध्ययन से पता चला है कि पौधों के साथ लागू किया अकार्बनिक सूत्रों के माध्यम से 100% RDF या 125% RDF अधिक जोरदार पौधों का उत्पादन किया।

माइक्रोन्यूट्रेंट्स के प्रभाव सल्फर आवेदन के साथ और बिना उच्च pH मिट्टी शर्त के तहत में cv. नेय पूवन केला ने संकेत किया है कि सल्फर 20g/plant कि आवेदन में मिट्टी के पीएच 8.6 से 7.8 कम किया हिंज़ोस्फेर मिट्टी में और संयंत्र विकास (12.5%) और उपज मानकों (14%) में काफी वृद्धि हुई नियंत्रण की तुलने में । इसके अलावा मनाया मिट्टी के आवेदन 5g $FeSO_4$ प्रति संयंत्र और पत्ते आवेदन0.5% $ZnSO_4$ और गंधक के साथ बोरेक्स (संयंत्र प्रतिशत 20g) नियंत्रण की तुलना में 41.2% अधिक गुच्छा वजन दर्ज की गई । इसी प्रकार, के पत्ते का आवेदन 0.5% $FeSO_4$, $ZnSO_4$ और बोरेक्स सल्फर के बिना 36.3% अधिक गुच्छा वजन के रूप में नियंत्रण की तुलना में दर्ज की गई।

*प्रत्यलेंकस काम्फिए* की ओर केले के प्रतिरोध के जैव-रासायनिक तंत्र पर एक अध्ययन में संकेत दिया कि आम तौर पर फीनोल् के ऑक्सीकरण एंजाइमों की गतिविधि, तनाव से संबंधित एंजाइमों और कुल फीनोल्स, लिग्निन और ठेन्निंस के स्तर उच्चप्रतिरोधी में 180 दिनों में भी अतिसंवेदनशील कृषिजोपजाति की तुलना में अधिक थे । इन ऊपर कहा एंजाइमों की प्रेरण निमेटोड चुनौती टीका लगाई पौधों में और अधिक चुनौती पौधों की तुलनामें अधिक थे।

## फसल सुरक्षा

तमिलनाडु के थेनी और करूर जिलों में निमेटोड घटना के लिए किए गए घूमना सर्वेक्षण से पता चला है कि रूट घाव निमेटोड (*प्रत्यलेंकस काम्फिए*) नेंद्रण, नेय पूवन और कर्पुरावल्लीतरह कलटिवर में गंभीर था, जबकि, रूट गाँठ निमेटोड (*मेलोइद्ग्यने इन्कोग्निटा*) अधिकतम cv. कर्पुरावल्ली में पाया गया था। इन दोनों नेमाटोड cv ग्रांड नैन में गंभीर थे,थेनी जिले में। या तो *प्रत्यलेंकस लिलासिनुस* 20g + नीम केक 500g/plant या *त्रिकोदर्मा विरिदे* 20g + नीम केक 500g/plant की मिट्टी आवेदन से रूट गाँठ निमेटोड की आबादी का एक महत्वपूर्ण कमी थी और उद्यम की वृद्धि और उपज मापदंडों से पता चला जब अनुपचारित नियंत्रण संयंत्र की तुलना में।

Cv नेय पूवन में *बेसिलस सुब्तिलिस* और *बेसिलस सेरेउस* के संयुक्तआवेदन में परिणामस्वरूप संयंत्र के विकास में 60% की वृद्धि और जड़ घाव निमेटोड जनसंख्या के अलग - अलग उपचार की तुलना में 90% कमी के साथ । पेट्रोलियम ईथर और डैएथ्य्ल ईथर व्युत्पन्न भिन्न अर्थात,E2, E3,और *कालोत्रोपिस गिग-न्तेअ* के E5, दोनों रूट घाव और जड़ -गाँठ नेमाटोड के 100% मृत्यु दर का प्रदर्शन जब 50% सान्द्र में 48 घंटों से अवगत कराया । मूसा जर्मप्लाज्म के प्रमुख नेमाटोड के खिलाफ स्क्रीनिंग के परिणामस्वरूप में 5 द्विगुणित और 8 थ्रीगुणित दोनों रूट घाव और जड़ –गाँठ नेमाटोड के लिए प्रतिरोधी की पहचान की गयी है।

नेंद्रण केले के पत्ते के षीठस के विलायक निष्कर्षण कार्म करने के लिए तुलना में वीविल्स की अधिकतम आकर्षण(48%) दर्ज की गई। विलायक निष्कर्षण विधि

का उपयोग कर डैमेथ्य्लीन क्लोराइड और हेक्सऍन ने cv. कर्पुरावल्ली में 10 से 15 अस्थिर घटकों की पहचान में परिणामस्वरूप हुई । कार्म और cv की पत्ती षीठस के विलायकअर्क कर्पुरावल्ली अधिकतम 44% और 38 क्रमशः की घुन आकर्षण संकेत दिया । फील्ड स्टेम थेनी और तमिलनाडु के डिंडीगुल जिले के घुनस्थानिकमारी वाले क्षेत्रों में कीप जाल का उपयोगमूल्यांकन से पता चला है कि घुन आकर्षण सेमिओकेमिकल नंबर 1 + मेजबान संयंत्रवाष्पशील cv. नेंद्रण से प्राप्त निकालने में अधिकतम (80%) था।

टिशू कल्चर ग्रैंड नैन संयंत्र का इंजेक्शन NRCB आइ-सोलेट्स के साथ एंडोफ्यिटक कवक, *ब्युवेरिया बस्सि-आना* (NRCB en. B. b No. 5, 12, 13 and 17) 12 से 32% के घुन मृत्यु दर दर्ज , जबकि मानक के साथ चेक की गई हिंज़ोस्फेरइक *ब्युवेरिया बस्सिआना* (No.18) ने 90 % वीविल्स की मृत्यु दर दर्ज की है।

या तो एंडोफ्यिटक ट्राइकोडर्मा BC2 तनाव के संयुक्त-आवेदन + हिंज़ोस्फेरइक टी. कोनिंगी (या) एंडोफ्यिटक ट्राइकोडर्मा एसपीपी Dsr1 तनाव + हिंज़ोस्फेरइक टी. कोनिंगी (या) एंडोफ्यिटक ट्राइकोडर्मा तनाव + prr2 हिंज़ोस्फेरइक *त्रिकोदर्मा हरजियानम* 30g/plant अलग को चावल खरब अनाज तैयार के रूप में लगाने से पूरी तरह से बर्तन संस्कृति की शर्तों के तहत फुसेरियम विल्ट रोग नियंत्रित हुई। अल्पिनिया एसपीपी के रूप में वनास्पथियो, हिबिस्कुस एसपीपी. और ज़िम्मू 11 / 2 घंटे के लिए पौधों की मिट्टीसराबोर सूई बर्तन प्रति 250 मिली लीटर फुसेरियम विल्ट घटना की 100% की कमी नियंत्रण की तुलना में दर्ज कीसाथ के रूप में लागू होता है।

सूक्ष्म परीक्षा और आणविक विश्लेषण में मैकोस्फरेल्ला एसपीपी के 96 आइसोलेट्स.केले के अलग अलग कलटिवर, भारत के विभिन्नक्षेत्रों में उगाई से अलग एम. यूमुसे की उपस्थिति का पता चला और यह दर्शाता है कि भारत में पत्ता स्पॉट रोग एम. यूमुसे की वजह से है। वंशावली विश्लेषण किया इन सभी आइसोलेट्स के डी. एन.ए अनुक्रम का उपयोग एम. यूमुसे आइसोलेट्स के बीच 11 विभिन्न समूहों की उपस्थिति का संकेत है । क्षेत्र शर्त के तहत रोग की शुरुआत के बाद 25 दिनों के अंतराल पर 4 बार के लिए एंडोफ्यिटक बैक्टीरियल तनाव (6m2) के छिड़काव, बिना छिडकाव किए नियंत्रण पौधों की तुलना में पत्ता स्पॉटगंभीरता के 43% की कमी दर्ज की। इन विट्रो कवक विरोधी, एम. यूमुसे रोगज़नक़ के लिए संवेदनशीलता परीक्षण संकेत दिया है कि सिगटोका पत्ता स्पॉट रोगज़नक़ 0.01 पर 1% सान्द्र प्रोपकोनाजोल, कार्बेन्डाजिम , मेंकोज़ेब , दैफेनोकोनाज और त्रैदेमोर्फ जैसे सभी व्यावसायिक रूप से उपलब्ध है, कवक विरोधी के प्रति संवेदनशील था । VAM आइसो-लेट्स की मिट्टी आवेदन ग्रैंड नैन में काफी वृद्धि हुई जड़ों की संख्या में (91-191%) और भी जड़ बायोमास (154 to 358%) पाट कल्चर के तहत में।

त्रिची और तंजावुर जिले में किए गए सर्वेक्षण में 3-8% BBTV और ऊतक सुसंस्कृत पौधों में,विशेष रूप से BBrMV रोगों के 1-10% संकेत दिया । Cv की दूसरी रट्टून फसल में. पूवन भी, उर्वरक (RDF के 150%) की वृद्धि की खुराक के आवेदन उपज BBrMV करने के लिए कारण हानि मुआवजा है । जैविक खाद की तुलना में अकार्बनिक उर्वरकों के साथ पूवन केले के निषेचन में BSV की बीमारी की गंभीरता में महत्वपूर्ण कमी दर्ज की गई थी । पहली बार, केले हल्के मोज़ेक वायरस (BaMMV) तिरुच्चिराप्पल्ली , तमिलनाडु, भारत में सूचना दी है । आठ विभिन्न BBrMV आइसोलेट्स तमिलनाडु, आंध्र प्रदेश और केरल से एकत्र , पूरी कोट प्रोटीनजीन के विश्लेषण पहले ही प्रकाशित NCBI में उपलब्ध दृश्यों की तुलना में भिन्नता तिरूकाट्टूपल्ली में विशेष रूप से 19% (तमिलनाडु) को अलग से पता चला है । प्राइमरों BBrMV का पता लगाने की संवेदनशीलता को बेहतर बनाने का एक नया सेट बनाया गया था और मान्य की गई थी। इसके अलावा, प्राइमरों के चार नए सेट मल्टीप्लेक्स-पीसीआर के द्वारा किया गया है चार वायरस के लिए पता लगाने की संवेदनशीलता में सुधार करने के लिए तैयार की गई थी।

प्राइमर्स और जांच (TaqMan जांच) के लिए डिज़ाइन किया DSMZ, जर्मनी के साथ सहयोग में BBTV और BSMysV, रोगसूचक नमूनों में वास्तविक समय पी.सी. आर (RT-पीसीआर) द्वारा BBTV की उपस्थिति का पता लगा सकता है।

रोलिंग सर्किल प्रवर्धन दृष्टिकोण (आर.सी.ए) पूवन और BBTV में हिल केले में BSMysV के एपिसोमल वायरस का पता लगाने के लिए मानकीकृत किया गया है। खट्टे में केले स्ट्रीक वायरस के संभावित सहयोग भी क्लोनिंग द्वारा स्थापित किया गया था और बैढ़ना वैरस संक्रमित खट्टे पत्ता नमूने के अनुक्रमण। प्राइमर्स और जांच BBTV के प्रतिनिधि जीन के लिए डिजाइन किया गया है और अव्यक्त में अपनीटेप और गंभीर संक्रमित पौधों वास्तविक समय पी.सी.आर का उपयोग की मात्रा का आकलन की गई है। प्राइमरों जो आसन्न झूठ से पडे हो (अबत्टिंग प्राईमर) के साथ वृत्त (आरसीए) प्रवर्धन और पीसीआर प्रवर्धन रोलिंग के आधार पर, यहपहचान की थी कि लकीर लक्षण cv में प्रदर्शित पूवन दोनों BSMysV और BSOLV प्रजातियों था।

## प्रौद्योगिकी के हस्तांतरण

2010-11 के दौरान, वैज्ञानिकों केंद्र ऑल इंडिया रेडियो, तिरुचिरापल्ली में चार रेडियो वार्ता दिया, 16 दूर्धर्शन और मक्कल टीवी, चेन्नई, में टेलीविजन वार्ता दिया और 11 क्षेत्रीय या राष्ट्रीय स्तर पर प्रदर्शनियों में भाग/आयोजन लिया। 12 छात्रों को अपने काम / परियोजना/ थीसिस के लिए एम.एस.सी / बी. टेक/ एम. फिल/ पी.एच. -डी डिग्री के पुरस्कार के लिए वैज्ञानिकों द्वारा निर्देशित किया गया। 12 शोध पत्र, 26 लोकप्रिय लेख, 16 पुस्तकों के अध्यायसात तकनीकी बुलेटिनों, चार एक्सटेंशन/ तकनीकी फ़ोल्डर्स, तीन फिल्म दस्तावेज़ों और 40 शोध पत्र राष्ट्रीय और अंतरराष्ट्रीय सम्मेलनों / संगोष्ठियों / सेमिनार / कार्यशालाएं बैठक में प्रस्तुत किए गए। 14 केले का उत्पादन और पोस्ट हार्वेस्ट प्रौद्योगिकी के पर परिसर में प्रशिक्षण का आयोजन किया गया। 20 अति विशिष्ट व्यक्तियों और +3,950 किसानों / कृषि अधिकारियों / स्वयं सहायता समूह आदि के रूप में कई केरूप में दौरा किया है और केंद्र की गतिविधियों का आकलन।

## राजस्व पीढ़ी

रुपये की कुल 25.15 लाख राजस्व के रूप में केन्द्र द्वारा महसूस किया गया था।

# 3 EXECUTIVE SUMMARY

## CROP IMPROVEMENT

*Musa* gene bank of NRCB was further strengthened by adding three accessions from Tripura and 28 ITC accessions including *M. textiles, M. boman, M. balbisiana* type Tani, from Belgium. A database was created for 90 accessions using Minimum Photo Descriptor by Taxonomic Advisory Group for *Musa*. Seven Bihar accessions were characterized using INIBAP/ IPGRI descriptor for 121 characters. Field evaluation of ECS regenerated plants of cv. Nendran revealed that ECS derived plants are performing better than the conventional derived plants such as suckers and shoot tip derived tissue culture plants. Evaluation of commercial cultivars based on their nutritional parameters has indicated that Pachanadan and Nendran are highly nutritious with respect to all minerals and carotenoids followed by Udhayam variety.

A database has been created to understand the best season for hybrid seed production and their regeneration. Although seed set was observed in flushes throughout the year, seed germination and plant regeneration could be achieved from seed set only during November - December months.

Regeneration of stored seeds of *Musa* spp. after 12 months at 24°C could be achieved (21.3 )by $GA_3$ soaking for 48 hrs. Similarly,soaking of freshly harvested hybrid seeds in gibberllic acid at 0.2 mg/ l for 72 hrs exhibited highest seed germination of 80.48 % compared to BAP and IAA treatments. Proliferation of embryogenic callus of cv. Grand Naine was achieved in MS medium supplemented with 0.01- 0.05% of activated charcoal. A simple and efficient protocol was developed for regeneration of plantlets from matured and immatured embryos of *M. acuminata* ssp. burmannica (AA) and this will facilitate the *Musa* improvement programme through conventional approaches.

Molecular marker studies on mutated and non-mutated plants of Rasthali showed high polymorphism in mutated plants. The ISSR analysis performed also clearly distinguished the non-mutated Rasthali plants from the mutated plants. A SSH library consisting 850 clones has been created for the Sigatoka resistant *Musa acuminata* cv. Manoranjitham challenged with *Mycosphaerella eumusae*. Out of 850 clones, 0.5% of genes were hit with the defense genes. The expression profiling of putative genes obtained from SSH library of *P. coffeae* resistant cultivar revealed that defense genes are up regulated both in susceptible and resistant cultivar, but, the transcript level was high and up regulated earlier than the susceptible cultivar. Expression of RGA specific primers, C6RGA was expressed only in resistant cultivar and not in the susceptible one.

## CROP PRODUCTION

Wider spacing (2.1 X 2.4m) and applied with 300:400g N&K per plant in Udhayam recorded the Lowest fruit acidity (0.45%) and the highest pulp: peel ratio (6.69). Besides, wider spacing plants also exhibited early flowering as compared to closer spacing. The root knot nematode population was the least (32.3/250g soil) in the widest spacing (2.1 X 2.4m)compared to the closest spacing. Planting of Udhayam banana with three suckers per pit at 3.6X3.6m spacing recorded the tallest plants (3.91m) where as, single plant per pit at 2.1 X 2.4m spacing recorded the shortest plants (3.65m). The study on the effect of organics on the BSV and BBMV infected Poovan showed that the plants applied with 100 % RDF or 125 % RDF through inorganic sources produced more vigorous plants.

Effect of micronutrients with and without sulphur application under high pH soil condition in cv. Ney Poovan banana indicated that application of sulphur 20g/plant reduced the soil pH from 8.6 to 7.8 in the rhizosphere soil and plant growth (up to 12.5%) and yield parameters (up to 14%) significantly increased over control. Also observed that soil application of 5g $FeSO_4$ per plant and foliar application of 0.5% $ZnSO_4$ and Borax with sulphur (20g/plant) recorded 41.2% more bunch weight than control. Similarly, foliar application of 0.5% $FeSO_4$, $ZnSO_4$ and Borax without sulphur recorded 36.3% more bunch weight as compared to control.

A study on the biochemical mechanism of resistance of banana to *Pratylenchus coffeae* indicated that generally the activity of phenol oxidizing enzymes, stress related enzymes and the level of total phenols, lignin and tannins were higher even at 180 days in resistant than in susceptible cultivars. The induction of these above said enzymes were more in the nematode challenge inoculated plants than in the unchallenged plants.

## CROP PROTECTION

Roving survey conducted for the nematode incidence in Karur and Theni districts of Tamil Nadu revealed that the root-lesion nematode (*Pratylenchus coffeae*) was severe in cultivars like Nendran, Ney Poovan and Karpuravalli, whereas, the root-knot nematode, (*Meloidogyne incognita*) was found maximum in cv. Karpuravalli. Both these nematodes were severe in cv. Grand Nain at Theni district. The soil application of either *P.lilacinus* 20g +neem cake 500g/plant or *T.viride* 20g +neem cake 500g/plant recorded significant reduction of root knot nematode population and increased growth and yield parameters in Udhayam as compared to untreated control plants.

Combined application of *Bacillus subtilis* and *B.cereus* in cv. Ney Poovan resulted in 60% increase in plant growth with 90% reduction of root lesion nematode population than individual treatments. The petroleum ether and diethyl ether derived fractions viz., E2, E3 and E5 of *Calotropis gigantea* exhibited 100% mortality of both root- lesion and root-knot nematodes when exposed to 48 hrs at 50% conc. Screening of *Musa* germplasm against major nematodes resulted in the identification of 5 diploids and 8 triploids resistant to both root-lesion and root-knot nematodes.

The solvent extraction of Nendren banana leaf sheaths recorded maximum attraction of weevils (48%) compared to the corm. Solvent extraction method using dimethylene chloride and hexane resulted in the identification of 10 to 15 volatile components cv. Karpuravalli. The solvent extracts of corm and leaf sheaths of cv. Karpuravalli indicated maximum weevil attraction of 44% and 38 respectively.

Field evaluation using funnel trap in stem weevil endemic areas of Theni and Dindigul districts of Tamil Nadu showed that weevil attraction was maximum (80%) in Semiochemical No.1 + host plant volatile extract obtained from cv. Nendran. The injection of tissue culture Grand Nain plant with NRCB isolates of endophytic fungi, *Beauveria bassiana* (NRCB en. B. b No. 5, 12, 13 and 17) recorded a weevil mortality of 12 to 32% whereas, the standard check with rhizospheric *B. bassiana* (No.18) recorded 90 % mortality of weevils.

The combined application of either endophytic *Trichoderma strain* BC2 + rhizospheric *T. koningii* (or) endophytic *Trichoderma* spp. strain Dsr1 + rhizospheric *T. koningii* (or) endophytic *Trichoderma* strain prr2 + rhizospheric *T.harzianum* isolate 30g/plant as rice chaffy grain formulation completely controlled the *Fusarium* wilt disease under pot culture conditions. The botanicals such as *Alpinia* spp., *Hibiscus* spp. and Zimmu applied as dipping of plants for 11/2 hrs + soil drench with 250 ml per pot recorded 100% reduction of *Fusarium* wilt incidence compared to control.

Microscopic examination and molecular analysis of 96 isolates of *Mycospharella* spp. isolated from different cultivars of banana, grown in different regions of India revealed the presence of *M. eumusae* indicating that the leaf spot in India is caused by *M. eumusae*. The phylogenetic analysis carried out using the DNA sequences of all these isolates indicated the presence of 11 different groups among *M. eumusae* isolates. The *in vitro* fungicide sensitivity test for *M. eumusae* pathogen indicated that the Sigatoka leaf spot pathogen was sensitive to all the commercially available fungicides such as Propiconazole, Carbendazim, Mancozeb, Difenoconazole and Tridemorph at 0.01 to 1% conc. Soil application of VAM isolates in Grand Nain significantly increased the no. of roots (91 to 191%) and also the root biomass (154 to 358%) under pot culture condition.

Survey undertaken in Trichy and Thanjavur districts indicated of 3-8 % BBTV and 1 -10 % BBrMV diseases especially in the tissue cultured plants. In the second ratoon crop of cv. Poovan also, application of increased dose of fertilizers (150% of RDF) has compensated the yield loss due to BBrMV. The fertilization of Poovan banana with inorganic fertilizers recorded significant reduction in disease severity of BSV compared to organic fertilizer. First time, Banana mild mosaic virus (BaMMV) is reported in Tiruchirapalli, Tamil Nadu, India. The analysis of complete coat protein gene of eight different BBrMV isolates collected from Tamil Nadu, Andra Pradesh and Kerala revealed 19% variation particularly in Thirukattupalli (Tamil Nadu) isolate compared to already published sequences available in the NCBI. A new set of primers to improve the sensitivity of detection of BBrMV was designed and validated. Besides, four new sets of primers have been designed for improving the sensitivity of detection of indicated four viruses by multiplex RT-PCR. Primers and probes (TaqMan probe) designed for BBTV and BSMysV in collaboration

with DSMZ, Germany could detect the presence of BBTV in symptomatic samples by real time PCR (RT-PCR).

Rolling Circle Amplification (RCA) approach has been standardized to detect episomal virus of BSMysV in Poovan and BBTV in Hill banana. Possible association of Banana Streak Virus in citrus was also established by cloning and sequencing of badnavirus infected citrus leaf sample. Primers and probe have been designed for rep gene of BBTV and assessed the quantity of its transcripts in latent and severely infected plants using real time PCR. Based on rolling circle amplification (RCA) and PCR amplification with abutting primers, it was identified that the streak symptom exhibited in cv. Poovan had both BSMysV and BSOLV species.

## POSTHARVEST TECHNOLOGY

A new product, banana pulp based 'Sip-up' was prepared without pasteurization. The product can be stored up to 15 days at 0°C.

## TRANSFER OF TECHNOLOGY

During 2010-11, the scientists gave four radio talks in All India Radio,Tiruchirapalli, 16 television talks in Doordharshan & Makkal TV, Chennai and participated/ organized 11 exhibitions at regional or national levels. 12 students were guided for their project/ thesis work for the award of M.Sc/ B.Tech/ M.Phil/ Ph.D degree by the scientists. 12 research papers, 26 popular articles, 16 books chapters, seven technical bulletins, four extension/ technical folders, three film documents and 40 research papers were presented in National and International Conferences/ Symposia/ Seminars/ Workshops/ Meeting. 14 on- campus trainings on Production and Postharvest technology of banana were organized. As many as 20 VIPs and 3,950 farmers / Agriculture officials/ SHGs etc, visited and were appraised the activities of the Centre.

## REVENUE GENERATION

A total of Rs. 25.15lakhs was realized as revenue by the Centre.

# 4 INTRODUCTION

The National Research Centre for Banana was established on 21st August 1993 at Tiruchirapalli, Tamil Nadu by the ICAR, New Delhi with an aim to increase the production and productivity of bananas and plantains through mission mode basic and strategic research approaches. This Centre is located at 11.50° N latitude and 74.50° E longitude, 90 m above MSL and receives 800 mm rain annually. The climate is warm and humid and the average min and max temperature are 25° and 35°C respectively. The Centre has a research farm with 36 ha land and infrastructure facilities like library, meeting and exhibition halls, green houses, quarantine lab and net houses.

The Centre works on four major thrust areas of research viz., Crop Improvement, Crop Production, Postharvest Management and Crop Protection. It has well-equipped laboratories for tissue culture, biotechnology, soil science, nutrient management, physiology and biochemistry, entomology, nematology, fungal, bacterial, viral pathology and postharvest technology research.

In late nineties, 10 collections surveys through explorations were made. Wild banana germplasm from the North - Eastern states, Western Ghats and Andaman and Nicobar islands and also exotic banana accessions from International Transit Center (ITC), Belgium through NBPGR, New Delhi were introduced. The Centre has completed seven in-house research projects and 11 are in progress in the 11th five year plan. In addition to Centre's in-house projects, 26 externally funded projects by APCess fund of ICAR, NATP, DBT, NHB and INIBAP were completed. The Perspective Plan and Vision 2025 documents on the research priorities and also inputs from QRT and RAC were published. The Centre conducts two meetings of Institute Research Council to review the on-going research projects and also to incorporate the RAC recommendations. The vision of the centre is to increase the production and productivity of bananas and plantains to meet the growing need in India.

### The mandates of the Centre are:

- To undertake the basic and strategic research for developing technologies to enhance the productivity and utilization of banana
- To develop improved cultivars through traditional and biotechnological methods and conserve the diversity
- To serve as national repository of germplasm and information related to banana and plantain and also to disseminate the knowledge to improve the production and productivity
- To provide leadership and coordinate the network research for generating location specific variety technology and for solving specific constraints on banana and plantain production
- To collaborate with relevant national and international agencies in achieving the above objectives

## Salient Achievements

### Crop Improvement

A total of 360 crore accessions have been collected from both indigenous and exotic sources, which are maintained in the Centre's gene bank at Tiruchirapalli and the satellite gene bank at Agali. Among the collections, 92 accessions are highly resistant and 25 are resistant to Sigatoka leaf spot disease. A SSH library consisting 850 clones has been created for the Sigatoka resistant *Musa accuminata* cv. Manoranjitham challenged with *Mycophaerella eumusae*. Of 850 clones, 0.5% of genes were hit with the defense genes. NRCB selection Udhayam, which belongs to Pisang Awak sub group, is a high yielder. Embryogenic cell suspensions (ECS) for five different commercial varieties viz., Rasthali, Nendran, Ney Poovan, Robusta and Grand Nain have been developed and regeneration protocol from ECS for Nendran and Rasthali has been standardized. Picloram based medium was found more efficient in the formation of somatic embryos in cvs. Rasthali and Nendran. Field evaluation of ECS regenerated plants are performing well than the conventional derived plants such as suckers and shoot tip derived tissue cultured plants. A simple and efficient protocol has been developed for regeneration of plantlets from matured and immatured embryos of cultivar *M. acuminata* ssp. *burmannica* (AA) and this will facilitate the *Musa* improvement programme through conventional approaches. The NRCB has developed a 'DNA Bank for *Musa* Germplasm' with 225 accessions. A farmer's friendly method of mass production of banana planting material called 'Macro

propagation' has been developed to meet the need of small and marginal farmers. Evaluation of commercial cultivars based on their nutritional parameters has indicated that Pachanadan and Nendran are highly nutritious with respect to all minerals and carotenoids followed by Udhayam banana. Database has been created to understand the best season for hybrid seed production and their regeneration.

## Crop Production

Poovan plants supplied with 20 liter water/day/plant and 75% N (150 g N/plant) as fertigation increased the yield by 20% with maximum net profit and a benefit cost ratio of 1.96. A combination of distillery sludge 2.5 kg + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure per plant recorded the maximum growth and yield parameters in Rasthali and Karpuravalli bananas. Application of gypsum 2 kg/plant + FYM 15 kg/plant + 120% recommended K in saline sodic soil increased the yield by 51% over control in Nendran and Rasthali bananas. Paired row planting system, which accommodated 4,500 - 5,200 plants/ha, increased the productivity and fruit quality with 75% recommended fertilizers dose as fertigation in Robusta, Grand Naine and Red Banana. Application of 15 kg rice husk ash + 25 g VAM + 80% recommended NPK gave an additional profit of Rs. 32,500/ha. Soil application of Fe and B along with foliar spray of Zn under high pH soil condition, increased the bunch weight of Ney Poovan banana by 43.5% over control, resulting in an additional net profit of Rs. 38,000/ha. Fertilizer adjustment equations for Poovan and Karpuravalli bananas were developed by following the Soil Test Crop Response and Targeted Yield Concept. Under high soil pH conditions, application of bentonite sulphur @20g/plant at three month after planting improved the plant height, number of leaves, total leaf area, number of fruits, bunch weight and leaf N, P, K, Ca, Mg and S content of Nendran banana. Effect of micronutrients with and without sulphur application on banana under high pH soil condition in cv. NeyPoovan indicated that the application of sulphur 20g/plant reduced the soil pH from 8.6 to 7.8 in the rhizosphere soil and increased the plant growth (upto 12.5%) and yield parameters (up to 14%) significantly over the control. The study on the effect of organics on the BSV and BBMV infected Poovan showed that the plants applied with 100 % RDF or 125 % RDF as inorganic sources produced more vigorous plants. Wider spacing (2.1 X 2.4m) and applied with 300:400g N&K per plant in Udhayam recorded the lowest fruit acidity (0.45%) and highest pulp: peel ratio (6.69). Besides, wider spacing plants also exhibited early flowering as compared to closer spacing. In the case of root knot nematode population, the widest spacing (2.1 X 2.4m) recorded the least nematode (32.3/250g of soil) population compared to closest spacing. Eight drought tolerant accessions were identified based on leaf water retention capacity. The leaf longevity was more in Robusta than Nendran, Rasthali and Ney Poovan bananas. Saba, Karpuravalli and Ney Poovan have been identified as tolerant cultivars to salt stress. Drought tolerant Saba and Karpooravalli cultivars maintained higher (>200) K/Na ratio in leaf (lamina and midrib) when compared with susceptible Ney Poovan, Nendran and Robusta cultivars (4.52 to 17.56) at shooting and fruit maturity. A study on biochemical mechanism of resistance of bananas to *Pratylenchus coffeae* generally indicated that the activity of phenol oxidizing enzymes, stress related enzymes and the level of total phenols, lignin and tannins were higher even at 180 days in resistant than in susceptible cultivars. The induction of these above said enzymes were more in the nematode challenge inoculated plants than in the unchallenged plants.

## Postharvest Technology

Pre-packaging in 400 gauge LDPE bags, low temperature storage, use of ethylene absorbents and pre-storage treatments have resulted in extension of shelf life up to 3 months in Robusta, Grand Nain, Rasthali and Ney Poovan bananas. Several value added products like flower thokku, peel thokku, fruit pickle, fig, biscuits, jam, ready to serve beverages and functional foods like chapathi, bread and health drink have been developed. Banana and Jamun juice blend was the best among the blends made with other fruit juices rich in antioxidants. A recipe for banana flower based ready to make soup has been standardized. A new product, banana pulp based 'Sip-up' was prepared without pasteurization. The product can be stored up to 15 days at 0°C.

## Crop Protection

Mass production technique for *Paecilomyces lilacinus,* (an egg parasite of root-knot nematode) using banana petiole and pseudostem has been developed. Integration of *P. lilacinus* with either

neem cake or *Tagetus* or *Solanum* torvum is useful for effective management of root-knot nematode. The combined application of *Bacillus subtilis* and *B. cereus* in cv. Ney Poovan resulted in 60% increase in plant growth with 90% reduction of root lesion nematode populations than individual treatments. The screening of *Musa* germplasms against major nematodes resulted in the identification of 5 diploids and 8 triploids resistant to both root-lesion and root-knot nematodes. Swabbing 0.06% Chlorpyrifos 20 EC on the pseudostem of 1.2 m height during 5th and 8th months completely controlled BSW incidence. Treating suckers with Monocrotophos 36 EC (14 ml/liter) followed by soil application of Carbofuran 3G at the rate of 30 g per plant each at 4$^{th}$ and 7$^{th}$ months after planting found effective against corm weevil. Pseudostem split trap swabbed with chaffy grain formulation of *Beauveria bassiana* trapped the stem and corm weevils better than traps swabbed with maize flour formulation. Of the 37 semiochemicals tested, maximum olfactory response by corm weevil was recorded to bisabol-ol, which found effective for banana corm weevil monitoring under field conditions. Field evaluation conducted using funnel trap in a weevil (*O. longicollis*) endemic areas of Theni and Dindigul districts of Tamil Nadu showed that the weevil attraction was maximum (80%) in the treatment of Semiochemical No.1 + host plant volatile extract obtained from cv. Nendran. Cross reaction between race 1 and race 2 of *Foc* has been observed in VCG analysis. Diversity of *Foc* isolates has been studied using RAPD, PCR-RFLP analysis of IGS region and the sequence analysis of rDNA-ITS region. Use of Carbendazim (0.1%) for dipping the suckers before planting followed by soil drenching in root zone (@ 1-2 lit at 2,4 & 6 month after planting) and stem injection(@2ml at 2,4 &6 MAP) effectively controlled the Fusarium wilt disease in Ney Poovan cultivar under field conditions. Combined application of either endophytic *Trichoderma* strain BC2 + rhizospheric *T. koningii* (or) endophytic *Trichoderma* spp. strain Dsr1 + rhizospheric *T. koningii* (or) endophytic *Trichoderma* strain prr2 + rhizospheric *T. harzianum* isolate @ 30g/plant as rice chaffy grain formulation completely controlled the *Fusarium* wilt disease under green house condition. Microscopic examination and molecular analysis of 96 isolates of *Mycospharella* spp. isolated from different cultivars of banana grown in different regions of India revealed the presence of *M. eumusae* indicating that the leaf spot in India is caused by *M. eumusae*. Soil application of increased dose of fertilizer (150% of RDF) in cv. Poovan has compensated the yield loss due to BBrMV. Polyclonal antiserum to BBTV was produced and ELISA technique has been standardized for detection. NA probe and PCR based diagnostic techniques have been developed for all the banana viruses. A multiplex PCR technique has been developed for detecting three banana viruses simultaneously. Complete genome of BSV infecting Poovan has been cloned and sequenced. Promoter sequences from BBTV were cloned and sequenced. Duplex PCR for all the four viruses CMV, BBrMV, BBTV and BSV has been standardized. Real Time- PCR technique for simultaneous detection of banana viruses was standardized. Rolling circle amplification (RCA) approach which uses bacteriophage Phi29 DNA polymerase has been standardized to detect episomal virus of BSMysV in Poovan and BBTV in Hill banana. Primers and probe have been designed for rep gene of BBTV and assessed the quantity of its transcripts in latent and severely infected plants using real time PCR.

## Transfer of Technology

During 2010-11, the scientists center gave four radio talks in All India Radio,Tiruchirapalli, 16 television talks in Doordharshan & Makkal TV, Chennai and participated/ organized 11 exhibitions at regional or national levels. 12 students were guided for their project/ thesis work for the award of M.Sc/ B.Tech/ M.Phil/ Ph.D degree by the scientists. 12 research papers, 26 popular articles, 16 books chapters, seven technical bulletins, four extension/ technical folders, three film documents and 40 research papers were presented in National and International Conferences/ Symposia/ Seminars/ Workshops/ Meeting. 14 on- campus trainings on Production and Postharvest technology of banana were organized. As many as 20 VIPs and 3,950 farmers / Agriculture officials/ SHGs etc, visited and were appraised the activities of the Centre.

## Linkages and Collaboration

The Centre has developed good linkages with international institutes viz., Bioversity International, France and QDPI, Australia. It collaborates with different national research institutions for different activities viz., NBPGR, New Delhi; BARC and CIRCOT, Mumbai; IIHR,

Bangalore; NHB and DBT New Delhi and all SAUs. Tissue culture industries involved in banana mass propagation, farmers, exporters, banana federations, State Horticulture and Agriculture departments and self-help groups are linked with the Centre for various research and developmental activities. NRCB also co-ordinates with AICRP (Tropical Fruits) Centers working on banana. The Centre has collaborated with CTCRI, Trivandrum (Kerala) and CPRI, Shimla (H.P.) for development of extruded product by blending banana, cassava and potato flours

## Revenue Generation

A total of Rs. 25.15 lakhs was was generated from virus indexing and sale of farm produces respectively during this reporting period.

## BUDGET DETAILS (REVISED ESTIMATE) FOR THE YEAR 2010-'11

| Head of Account | PLAN Amount (Rs. in lakhs) | NON PLAN Amount (Rs. in lakhs) |
|---|---|---|
| Establishment charges | 0.00 | 270.00 |
| OTA | 0.00 | 0.10 |
| Travelling Allowances | 4.00 | 2.00 |
| Other Charges | 89.00 | 44.50 |
| HRD | 4.00 | 3.00 |
| Equipments | 27.96 | 1.40 |
| Works | 172.04 | 0.00 |
| Furniture& Fixture | 2.00 | 0.00 |
| Library books& Information Technology | 1.00 | 0.00 |
| **Total** | **300.00** | **321.00** |

# 5 RESEARCH ACHIEVEMENTS

## 5.1 CROP IMPROVEMENT

### 5.1.1 Genetic Resource Management

#### Improvement and management of banana genetic resources

#### Collection

During 2010-11, three accessions, each belonging to AAA-unique, Silk and wild *M. balbisiana*, have been collected from Tripura and added to the genebank. Survey in Theni district of Tamil Nadu resulted in the collection of 61 superior tissue culture clones of Grand Nain which were identified for three parameters namely, high yield, earliness and short stature.

Total 188 accessions were received from NBPGR (which include 50 general and 38 reference accessions of exotic origin) as proliferating cultures. Of these, 30 are reference accessions and 29 are general accessions, which have been successfully regenerated as *in vitro*. 154 plants blelong to 28 ITC accessions have been planted in the field. Among these, 11 ITC accessions including, *M. textilis, M. boman*, *M. balbisiana* etc. were found to be recalcitrant for regeneration and multiplication in normal MS medium. Hence, different modified MS media were tried, of which, MS medium fortified with growth promoters (BAP and IAA) was found successful for shoot proliferation.

#### Characterization

Seven out of 23 accessions collected from Bihar during 2009-10 have been characterized using INIBAP/ IPGRI Descriptor for 121 characters. Database has been created for 90 accessions using Minimum Photo Descriptor defined by Taxonomic Advisory Group for *Musa*. The genetic stability tested using ISSR markers indicated that incorporation of low cost alternatives in the multiplication of variety Udhayam through tissue culutre has not caused any significant variations at the genetic level.

#### Evaluation

#### Field evaluation of ECS regenerated plants of cv. Nendran

Plants produced through somatic embryogenesis was compared at its shooting stage with shoot tip and sucker derived plantlets for the parameters like pseudostem height, girth, petiole length, number of leaves and leaf area (Table 1). It was observed that mean height of the plants derived from three different sources was 286.67. Among three sources, pseudostem height was maximum in ECS derived plants (289.3 cm) followed by shoot tip derived plants. Other parameters like petiole length and leaf area had no significant difference with the exception of leaf area. Sucker raised plants, flowered earlier than *in vitro* derived plants (271.5 days) followed by shoot tip (273.2 days) and ECS (277.6 days) derived plants. Bunch weight and other yield parameters exhibited non-significant results.

#### Phenotypic variations

Plants obtained through somatic embryo genesis showed growth patterns similar to that of shoot tips and conventional suckers derived plants in terms of pseudostem height, girth, number of leaves, leaf size and leaf area and fruiting characteristic features, yet some morphological variations which were statistically significant were observed. ECS plants showed 0.9% variation followed by shoot tip derived plants (0.22%) and nil in conventional suckers. Change in colour of leaves from dark green to dull green, in ECS derived plants was recorded in higher percentage

**Table 1. Evaluation of plants originating from different explants for biometric data in cv. Nendran**

| Source | Parameters | | | | |
|---|---|---|---|---|---|
| | Pseudostem height (cm) | Pseudostem girth (cm) | No. of leaves at shooting | Petiole length (cm) | Leaf area (x 104) |
| Sucker | 261.7±3.0c | 76.2±0.8a | 10.9±0.4c | 42.4±0.8ab | 12.5±0.7ab |
| Shoot tips | 281.89±3.3ab | 66.3±0.5b | 12.7±0.09ab | 42.3±0.8babc | 11.3±0.3abc |
| ECS | 289.3±2.8a | 60.8±0.5bc | 13.9±0.3a | 43.9±0.6a | 12.8±0.5a |

**Table 2. Field observation of extent of variation (%) of plants derived from different explants.**

| Source | Types of variations (%) | | | |
|---|---|---|---|---|
| | Variegated leaves | Deformed leaves | Change in colour | Total variation |
| Sucker | 0.00±0.85c | 0.00±0.90c | 0.00 c | 0.00±0.50c |
| Shoot tip | 0.2±0.75b | 0.01±1.0b | 0.01±1.0b | 0.07±1.2b |
| ECS | 0.90±0.90a | 1.0±0.95a | 1.2±1.3a | 0.90±0.95a |

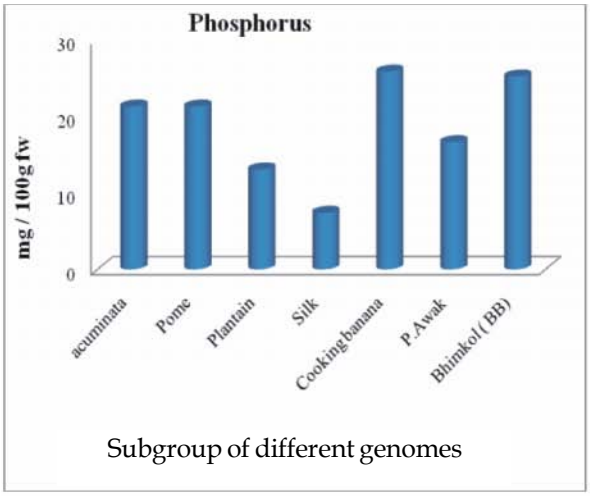
compared to other variations like deformed, mottled and variegated(Table 2).

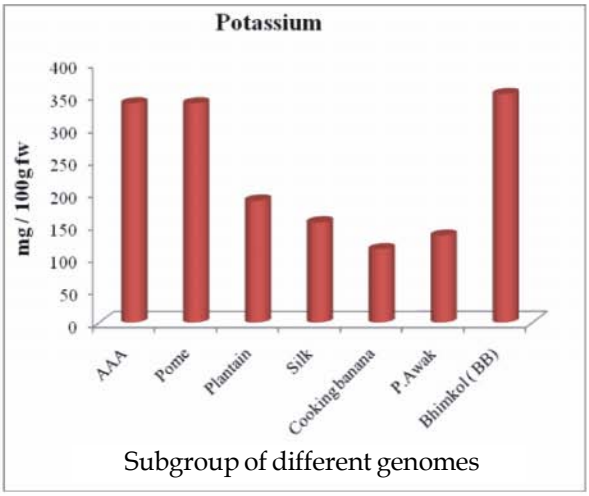
## Evaluation of commercial banana varieties for nutritional qualities

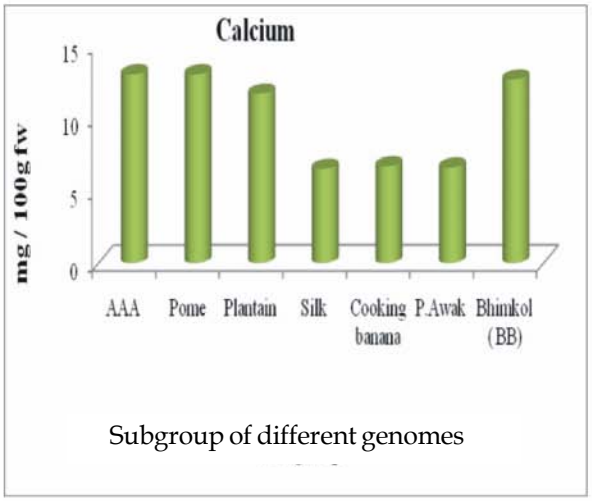
Fourteen commercial banana cultivars representing major array of genomes (AAA, AAB, ABB and BB) were used in the present study. This includes cultivars like Grand Nain (AAA), representing more than 60% of the national banana trade. Other cultivars of commercial with AAA genome like Robusta and other unique (AAA) niche cultivars like Red Banana, Thella Chakkarakeli and Amrit Sagar were included for comparison.

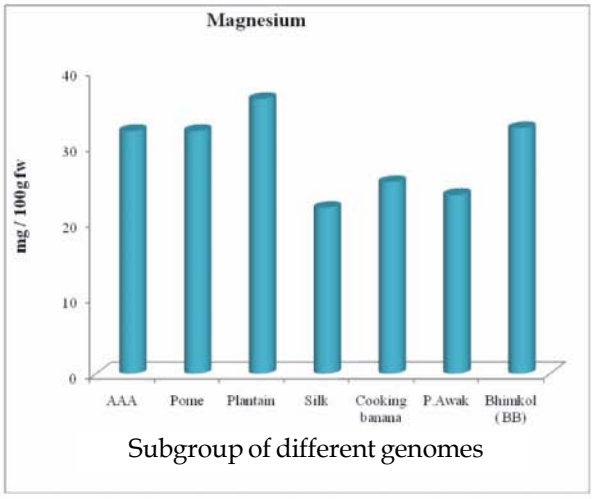
Scoring of commercial cultivars based on their nutritional status suggested that cvs. Pachanadan and Nendran are highly nutritious followed by NRCB released variety Udhayam. Bhimkol, inspite of its semi wild *balbisaina* status, ranked fourth due to its high potassium, calcium, iron and manganese contents while the choice cultivar, Rasthali, ranked the last among the cultivars tested (Fig. 1).

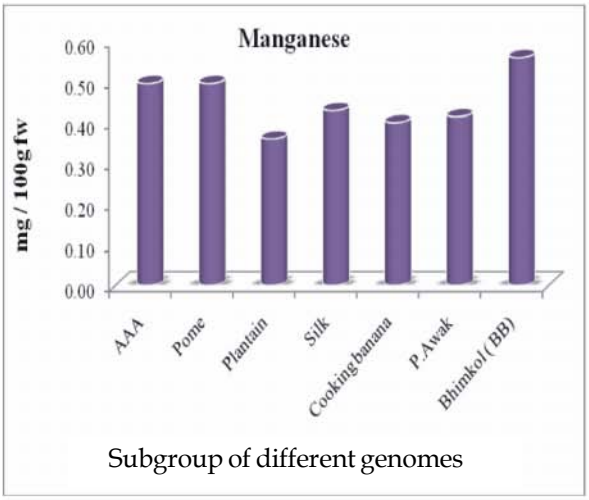
**Fig. 1 Nutritional diversity among commercial banana varieties**



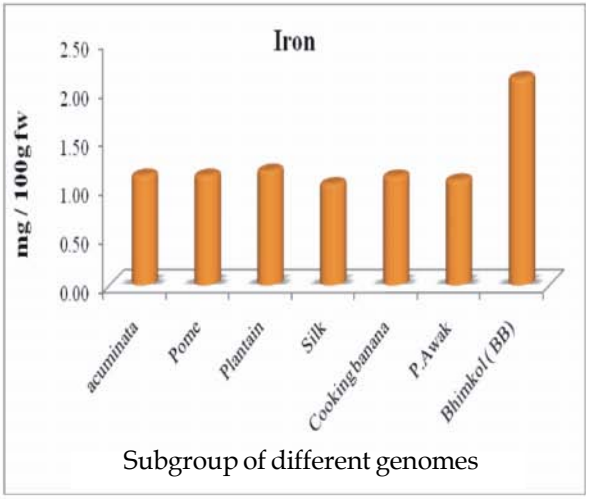



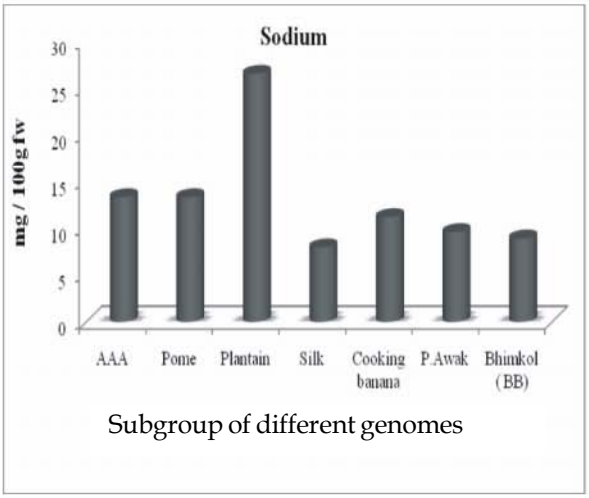





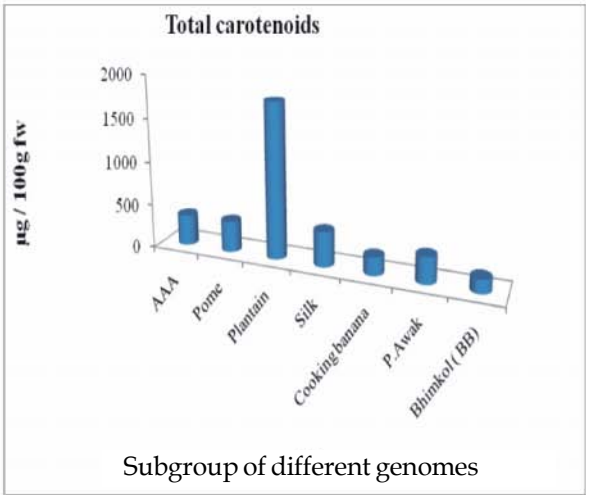
Subgroup of different genomes



Subgroup of different genomes



Subgroup of different genomes



Subgroup of different genomes

## Utilization

During the reporting period, Grand Nain and obusta samples from 10 different tissue culture companies have been tested for their fidelity using markers and they have been issued with test reports under DBT - ATL.

## 5.1.2 Development of tissue culture protocol for mass multiplication of Udhayam

MS medium fortified with BAP at 3 mg $l^{-1}$ and 5% coconut water, produced more number (6.3) of longer shoots (2.3 cm) in a shorter period of 7.5 days (Table). MS medium fortified with 0.5 mg $l^{-1}$ IBA, 1.0 mg $l^{-1}$ NAA and 0.25% activated charcoal produced maximum number of roots (4.7) in a minimal time of 7.7 days. Cocopeat and vermiculite at 1:1 ratio was optimum for primary hardening of cv. Udhayam in terms of plant height and root number (Fig. 2a). Dipping of rooted plantlets for half an hour in a bacterial cell suspension (PC2) under partial sunlight promoted the growth and development of tissue cultured plantlets during primary hardening (Fig. 2b). Use of commercial VAM in the potting mixture did not have any positive influence on the growth of tissue cultured plants during secondary hardening.

**Fig.2(a) Effect of various growth media on primary hardening of variety Udhayam**

**Fig.2(b) Effect of various microbial strains on growth of *in vitro* raised plantlets of variety Udhayam**

## Studies on the use of low cost alternatives in tissue culture on banana variety Udhayam

Micropropagation of banana variety Udhayam was carried out in MS medium containing low cost alternatives for water, gelling agent and carbon source. Preliminary trials revealed that the best water and carbon sources were Reverse Osmosis water (R.O)and Table sugar 3% respectively. Using the aforesaid water and carbon sources, attempts were made to determine the best combination of gelling agents both for the initial establishment and shoot proliferation. Results indicated that 0.1% agar in combination with the low cost gelling agents produced earlier greening and more no. of shoots in a short time span (14days) compared to control.

## Effect of Isabgol and water sources on the initial establishment of shoot meristem of variety Udhayam

Among the R.O water and single distilled water sources tried, R.O. water was best in terms of earlier greening. Among the various treatments tried, for the initial establishment and early greening of explants 3.5% Isabgol + 0.1% agar was found to be the optimum mudium.

Highly significant differences existed among arious treatments tried for days taken for first leaf emergence and no. of shoots produced per explant. The days taken for leaf emergence ranged from 20.20 (control) to 30.40 days (TI3), while the no. of shoots produced per explants was minimum (7.0) in TI3 and maximum (10.4) in (TI2). Hence TI2 (3% Isabgol + 0.1% agar) was found to be best as it produced the maximum of 10.4 shoots within 30 days.

Among the three gelling agents tried, Isabgol at concentrations 3% and in combination with agar (0.1%) gave better results in terms of production of more no. of shoots per explant. This suggested that during the initial establishment, the firmness of the medium is expected to be more to facilitate the inoculation of explants but in subsequent stages of shoot proliferation, it could be reduced to a smaller extent, as it brings down the production cost (Fig. 3).

**Fig.3 Effect of Isabgol in combination with agar on the initial establishment and shoot proliferation of banana variety Udhayam**

Control – 0.75% Agar
$T_1$ – 2.5% Isabgol + 0.1% Agar
$T_2$ – 3% Isabgol + 0.1% Agar
$T_3$ – 3.5% Isabgol + 0.1% Agar

## 5.1.3 Improvement of banana through conventional breeding

### Breeding work

For the improvement of Pisang Awak and developing culinary bananas resistant to Fusarium wilt and Sigatoka leaf spot diseases, 300 plants of nine different Pisang Awak types like Karpuravalli, Udhayam, Bankela, etc., and Kothia types at NRCB and 500 plants of cultivars like Karpuravalli, Bankela, Udhayam and Kothia etc., Agali along with potential male parents was established.

During this period, 798 bunches (148 at Agali and 650 at NRCB) containing 95,760 fruits were crossed involving 67 cross combinations (AA x AA, AAA x AA, AB x AA, AAB x AA, ABB x AA, ABBB x AA, BB x AA ) resulting in 20,043 seeds. Out of 67 cross combinations, seeds from 24 cross combinations were germinated either under *in vivo* (<1.0 % germination) or *in vitro* (4 - 12% germination). A total of 43 progenies were developed during 2009-10 and are planted in the field.

A separate progeny block was established with 105 progenies with 3 replications for evaluation and morphotaxonomic characterizations. Out of 59 progenies taken to the field, 10 have come to flowering which have been characterized for 121 characters and are being multiplied for evaluation against specific traits.

## Seed regeneration studies

### Studies on effect of growth hormones in breaking seed dormancy

Freshly harvested seeds from the hybrids of Pisang Jajee (AA) x *M. a. ssp burmanicoides* (AA) were soaked in various concentrations of BAP, GA3 and IAA for 72 hrs and water was used as control. Highest seed germination was recorded at 10mg per litter GA3 (80%) followed by 5mg per letter 3AP (70.1%) and 10mg per letter IAA (62.04%). Significant differences only with GA3 highest (80.48%) seed germination.

Irrespective of the hormonal treatment days taken for shoot and root emergence was non significant and ranged from 5-7 days after incubation. Plantlets regenerated from seeds pretreated with GA3 exhibited greater vigor in terms of number of shoot and roots compared to others, whereas, IAA treatment produced vigorous growth of roots over shoot and leaf production.

### Suitable pollination season for hybrid seed production

Database has been created to understand the effect of pollination season for hybrid seed production and their regeneration. Maximum seed set was observed in the bunches crossed during the month of October (214 bunches) at NRCB (Trichy) during 2009. At Agali, maximum seed sets was observed during November, 2009. Although seed set was observed in flushes throughout the year, seed germination and plant regeneration could be achieved from seed set occured only during November - December months (Fig.4 -a&b). The percentage of seed regeneration was better in seeds set in Agali than from Trichy location.

**Fig.4(a&b) Influence of seson on seed set and germination**

Fig.4(a)

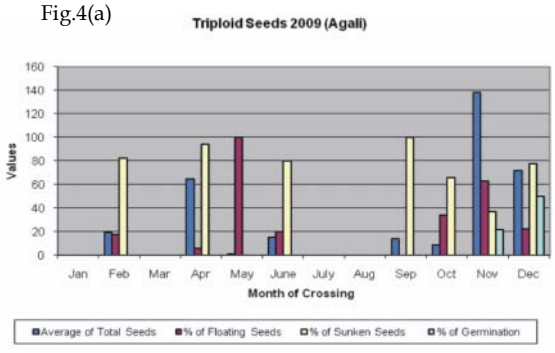
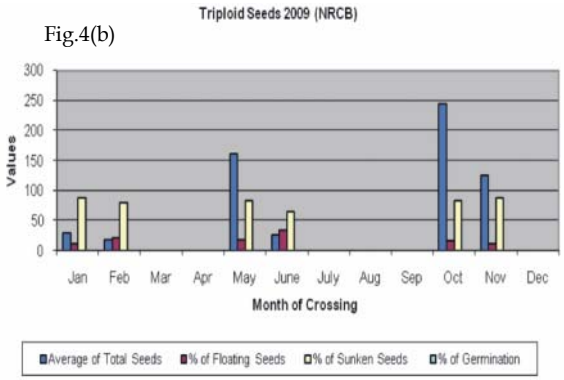



Fig.4(b)




### Enhancing the germination percentage of stored seeds of *M.Balbisiana*

Stored seeds of *M.Balbisiana* were treated with different concentration of gibbrelli acid. Results obtained showed that all concentrations of $GA_3$ were found effective in breaking the dormancy and enhancing germination compared to water as control (Fig. 5). Among various concentrations tried, 0.5 mg/ l $GA_3$ proved effective throughout the culture period studied and also showed that plantlets can be successfully regenerated from the seeds stored for longer duration (9 months). It was also observed that regeneration capacity increased with increase in concentration of $GA_3$ from 0.2 mg $l^{-1}$ to 0.5 mg $l^{-1}$ and beyond which it failed to show significant effect on plantlet recovery.

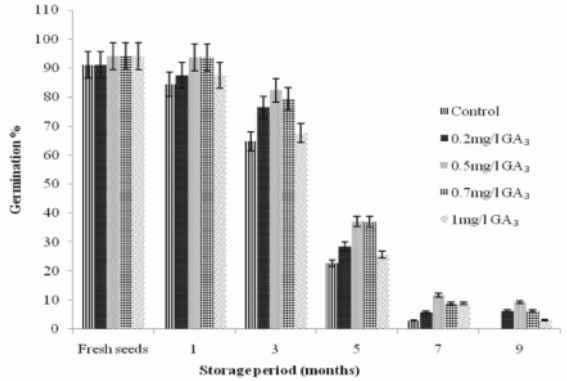



**Fig.5 Effect of soaking of stored seeds (M. a ssp. burmannica) in $GA_3$ on the germination.**

### Effect of storage on germination of embryo

Trials on the effect of culture time lag revealed that on an average, freshly harvested seeds recorded the earliest and highest germination (77.87%) across various cross combinations. Fresh seeds also produced quick root and shoot formation exhibiting minimum days for complete plantlet formation (47.33 days).

## Optimum perod for enhancing the servival percentage of embryo derived plants

Duration of embryo held *in vitro* germination medium, exhibited a parabolic curve with respect to final survival of plantlets. Plantlets of 80-90 days old were the best for shifting to primary hardening (with 5-6 leaves and 3-4 roots) and beyond which, it reduced the survival drastically (Fig. 6).

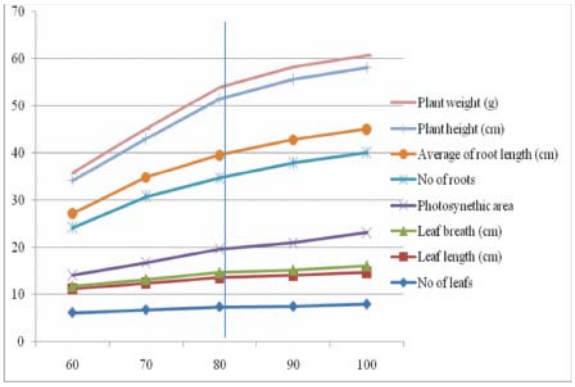



**Fig. 6 Effect of duration on embryo regeneration into plantlets**

**Phenotyping of F1 progenies -** 37 progenies have been phenotyped for 121 morpho taxonomic characters. Nutritional contents of partheno carphic progenies are being completed for four progenies.

## Multilocation testing of NRCB selections

NRCB selection -3 plants have been raised through tissue culture and 30 plantlets each have been supplied to BRS, Kannara, TNAU, Coimbatore and BRS, Kovvur.

## 5.1.4 Improvement of banana through non-conventional methods

## Development and regeneration of embryogenic cell suspensions

Proliferation of embryogenic callus in cv. Grand Nain was achieved in MS medium supplemented with 0.01 to 0.05% of activated charcoal. Establishment of homogenous cell suspension was achieved by the use of ideal callus, initiation of suspension with 3-5 ml of medium, gradual scaling up of material to 15 ml in 30 to 45 days, removal of vacuolated, meristematic globules and matured embryos while sub culturing. Modified regeneration medium (Picloram based medium) used for other commercial cultivars failed to induce somatic embryos from ECS of cv. Grand Nain. Induction of somatic embryo from embryogenic complex was achieved in the cytokinin (6-BAP) based medium.

## Plant regeneration through somatic embryogenesis from matured and immatured zygotic embryos of *Musa acuminata ssp. burmannica*

A simple and efficient protocol has been developed for regeneration of plantlets of cultivar *M. acuminata* ssp. *burmannica* (AA). Somatic embryos were produced when explants of immature and matured zygotic embryos were cultured on MS medium supplemented with plant growth regulators (2, 4-D, Picloram, BA and IAA). Immature embryos responded better in comparison to matured embryos. Callus proliferation was maximum in the medium supplemented with 2, 4-D (1mg/ l) (Table 3). Subsequent transfer of callus to fresh medium produced rapidly proliferating embryogenic calli. Regeneration of embryogenic calli into plantlets was high in immature embryos (79.7%) than in matured embryos (51.5%). The efficiency of regeneration of matured embryos was reduced (3.1%) on storage for 9 months as compared to harvest (94.1%). This could be improved by using gibberllic acid (0.5 mg/ l) (Table 4). This protocol of plant regeneration from matured and immatured embryos can improve breeding through conventional approaches.

**Table 3. Effect of media on embryo germination of immatured zygotic embryos**

| Medium | Number of embryos | Frequency of callus induction (%) | Embryogenic calli (%) | Germination (%) |
|---|---|---|---|---|
| M1 | 31 | 35.6±0.6h | 27.1±0.6h | 21.5±0.7h |
| M2 | 32 | 74.9±0.7e | 69.7±0.5c | 54.7±0.5d |
| M3 | 32 | 71.4±0.6f | 63.2±0.8d | 62.6±0.6c |
| M4 | 34 | 85.9±0.7b | 79.7±0.5a | 76.6±0.6a |
| M5 | 31 | 93.4±0.4a | 54.3±1.2f | 49.5±0.8e |
| M6 | 35 | 57.1±0.5g | 55.6±0.6e | 47.4±0.7f |
| M7 | 36 | 75.1±0.6d | 77.6±0.8b | 70.5±0.9b |
| M8 | 32 | 84.0±0.4c | 48.4±0.6g | 46.5±0.9g |

Means in the same column followed by different letters are significantly different (PD 0.05) by the student's t-test.

**Table 4. Effect of media on embryo germination of matured zygotic embryos**

| Medium | Number of embryos | Frequency of callus induction (%) | Embryogenic calli (%) | Germination (%) |
|---|---|---|---|---|
| M1 | 34 | 14.5±0.6h | 5.8±0.6h | 2.7±0.4h |
| M2 | 34 | 52.9±0.5b | 51.5±0.8a | 50.6±0.6a |
| M3 | 36 | 38.8±0.5d | 34.5±0.7c | 39.4±0.5c |
| M4 | 35 | 37.1±0.6e | 33.6±0.9d | 31.4±0.8d |
| M5 | 33 | 27.1±0.5g | 19.5±0.5g | 23.5±0.7f |
| M6 | 33 | 54.4±0.5a | 47.4±0.9b | 48.4±0.9b |
| M7 | 33 | 42.2±0.6c | 30.4±0.8e | 26.6±0.7e |
| M8 | 32 | 35.6±0.8f | 22.5±0.6f | 14.6±0.5g |

Means in the same row followed by different letters are significantly different (CD 0.05) by student's t-test.

### 5.1.5 Development of genetic linkage maps in *Musa*

Genomic DNA of the parents and 96 progenies of cross Phirima wild (BB) X Calcutta 4 (AA) was isolated and purified manually adopting the CTAB method of Gawel and Jarret (1991) with minor modifications. Initially, analysed genetically using 10 SSR markers. Out of 10 SSR markers screened, only three have shown polymorphism. Therefore, efforts are being made to identify more polymorphic markers for use in linkage mapping (Fig. 7).

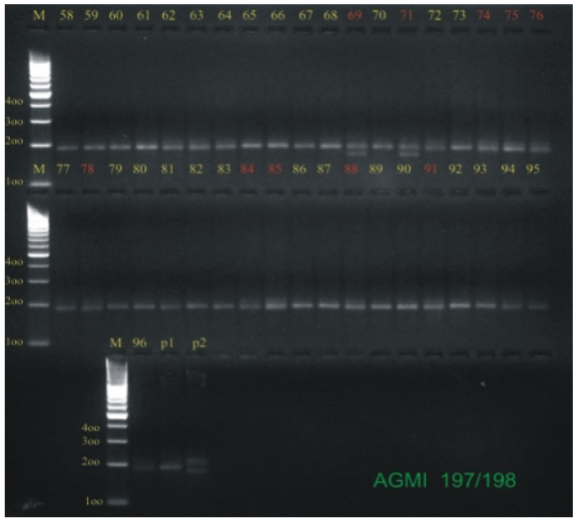



**Fig. 7 Microsatellite marker AGMI series 197/198 showing the parental recombination in some of the progenies (marked in red)**

### DNA barcoding in elite and indigenous landraces of *Musa*

Initial attempts made towards the development of DNA barcodes for the elite indigenous land races have led to the amplification

of four varieties namely Matti, Udhayam, Sannachenkadali and Anaikomban by using primer specific to intron ndh A (non-coding chloroplast DNA loci) (Fig. 8). The amplified products from the two varieties namely Matti and Udhayam have been eluted and cloned successfully and they are being sequenced.

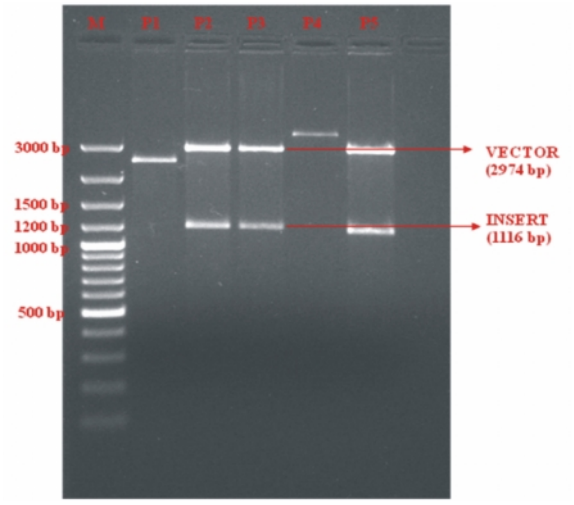



**Fig. 8 Restriction digestion by Bgl II enzyme to confirm the presence of insert in *cv*. Matti after cloning**

## 5.1.6. Improvement of Rasthali through induced mutagenesis

Mutated plants of various mutagenic treatments have been planted in the field for evaluation of desirable agronomic traits and are in vegetative phase (Fig. 9). Another set of the same treatments have been challenged with *Fusarium* race -1 pathogen for screening against *Fusarium* wilt resistance under pot culture condition (Fig. 10).

**Fig. 9 Field evaluation of mutated plants for desirable agronomic traits**

**Fig.*10 In vivo* screening of mutated Rasthali for *Fusarium* wilt resistance**

A total of 54 mutated plants of Rasthali along with control were tested for their genetic fidelity using molecular markers (SSR and ISSR) and the analysis was carried out in two batches. In the first batch of mutant analysis, the percent polymorphism was higher in SSR (50%) as compared to ISSR (30.20%) and the mutated plants were 19-21% different from the non-mutated Rasthali plants (Fig. 11).

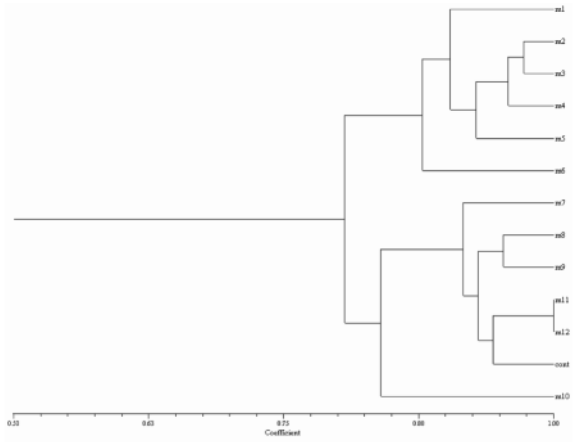


**Fig.11 Dendrogram (ISSR) showing the genetic variability between the mutated and non- mutated Rasthali plants**

In the second batch of (AGN/127/128) molecular analysis of mutants, SSR markers did not show any polymorphism, but 64.51% polymorphism was observed while using 10 selected ISSR markers. A total of 80 bands were polymorphic among the 124 strong, clear, and reproducible bands which were scored for the genetic analysis. The number of bands amplified by UBC 834 and UBC 868 were varied between 6 and 20 respectively with the product size ranging from 100 to 2500 bp (Fig. 12). The highest polymorphism of 92.85% was obtained with primer UBC 807, whereas, the lowest polymorphism of 20% was obtained with primer

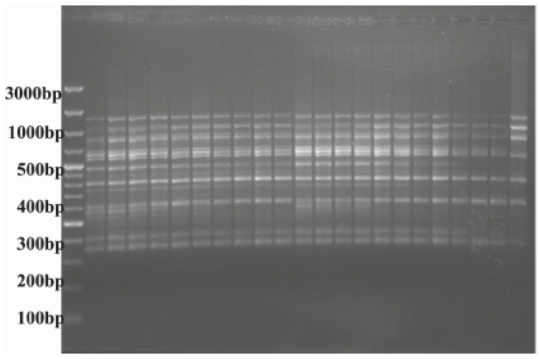



**Fig. 12 Genetic analysis of mutants using ISSR marker (UBC 868)**

UBC 841. The cluster analysis revealed that ISSR was able to differentiate the non-mutated Rasthali plants from the mutated plants (Fig. 13). Among mutants there were only 5% dissimilarities and 35 - 40% dissimilarities from the non-mutated control which was unique and stood in a separate cluster.

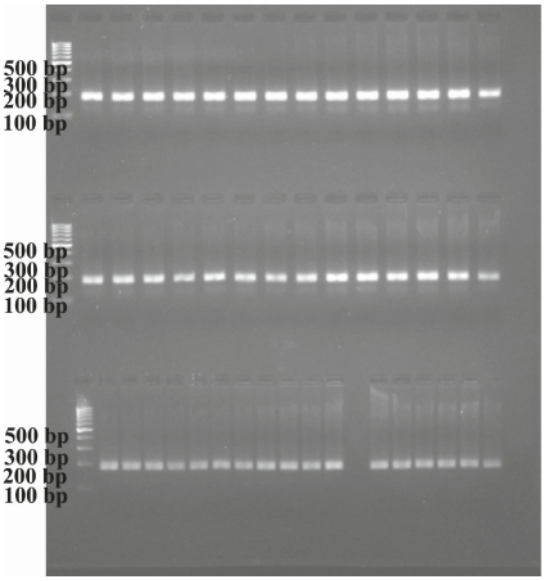



**Fig. 13 Genetic analysis of mutants using SSR (AGMI 127/128)**

## 5.1.7 Functional genomics of Sigatoka and Drought

### Proteomic analysis

The proteomic approach was initiated to identify protein(s) expressed in response to Sigatoka resistance in Banana (*Musa* spp.) Protein extraction protocol has been standardized for different banana tissues. Two standard protein extraction protocols like phenol extraction methanol/ammonium acetate precipitation and TCA-Acetone precipitation methods with few modifications were tried to isolate the protein from banana leaf tissues. Based on the resolution of protein bands, phenol coupled with ammonium acetate precipitation protocol was found to be the best. This protocol various leaf samples at differential maturity status like *in-vitro* maintained, secondary hardened and sucker raised plantlets (Fig.14).

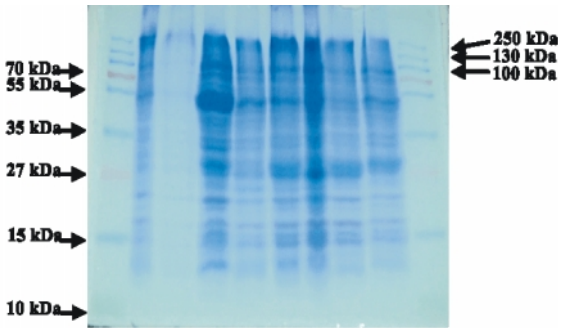
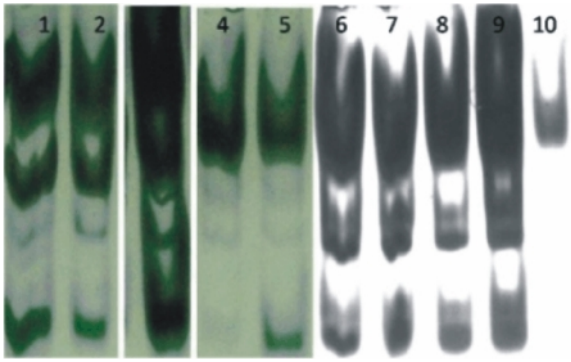



**Fig: 14 One Dimensional SDS-PAGE separation of proteins from Banana leave samples across various maturity stages**
Lane M: Pre stained Protein ladder Size 10-250kDa
Lane 1&2: Invitro raised plantlets
Lane 3&4: Primary hardened plants
Lane 5&6: Secondary hardened plants
Lane 7&8: Field raised plants

### Peroxidase enzyme profile in *Musa* accessions across different genomic groups

A total of 53 *Musa* accessions of different genomic groups were analysed for peroxidase enzymes, based on the concept that peroxidase is the one of the most important scavenging enzymes under abiotic stresses. The peroxidase enzyme analyses were carried out in 8% non-denaturing polyacrylamide gel at 40°c. The results indicated that even under normal conditions, diploid *Musa* cultivar Imbogo (drought tolerant) showed higher

**Fig. 15 Peroxidase enzyme profile in different *Musa* accessions**




1. Anaikomban (AA); 2. Namarai (AA);3. Imbogo (AA); 4. Athiakol (BB); 5 Musa balbisiana (BB); 6. Saba (ABB); 7. Jillegudam Collection (ABB); 8. Bluggoe (ABB); 9. Ashy Batheesa (ABB); 10. Manjavazhai (ABB)

level of peroxidase enzyme expression when compared to Namarai (susceptible) (Fig. 15).

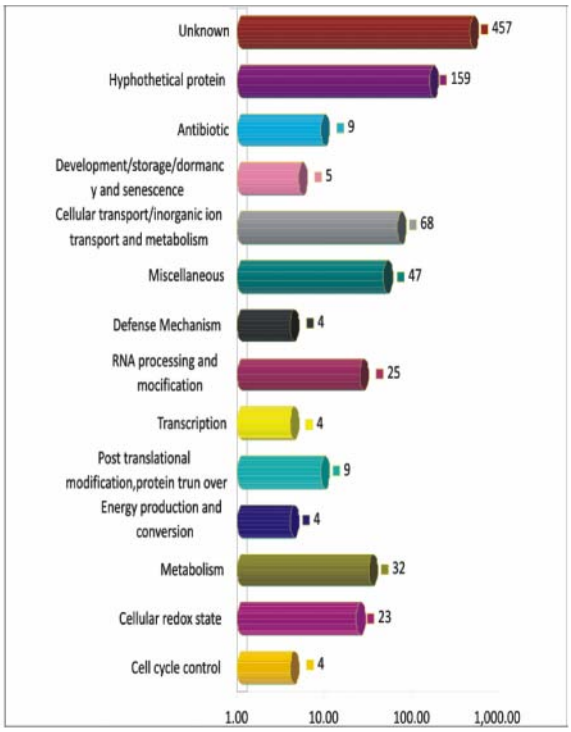
## Glycoproteomics

Post-translational modifications respectively (Fig. 16) (PTMs) of plant proteins play a crucial and direct role in stress signal transduction and acclimation processes. Therefore, in order to identify the glycoproteins (one of the signaling proteins involved in many cellular processes), a specific staining method has been standardized using leaf sap to detect major glycoproteins in polyacrylamide gel. For this, leaf sap protein extraction protocol has been developed. The glycoproteins analysis revealed that significant variation occurred among the *Musa* accessions. This diversity for glycoprotein content is being further studied using high throughput analysis.

## Identification of Sigatoka (*M.eumusae*) resistant genes through Functional Genomics approach

A Suppressive Subtraction Hybridization library has been created for the Sigatoka resistant *Musa acuminata* cv. Manoranjitham challenged with *Mycosphaerella eumusae*. A total of 850 EST's are identified in differential screening and they are deposited in the NCBI-GenBank repository. CAP3 analysis showed that all these assembly of sequences produced 297 singletons and the remaining sequences were grouped into 58 contiguous sequences (contigs). All these ESTs were categorized into 13 major groups based on their functions (Hypothetical proteins, antibiotic resistance, cellular developmental, senescence, transport, metabolism, miscellaneous, defence, RNA spilicing, transcription, post translational modifications, energy production,cellular redox state enzymes, cell cycle control and unknown which do not hit any of the GenBank accessions). Annotation of the assembled unigene set, through homology searches in the NCBI nucleotide databases revealed that 53.76% of the unigene set did not hit with any of the sequences submitted with NCBI. Similarly, 18.71% of unigene set were hit with hypothetical protein. These results suggested that further in-depth study is required on these genes which may provide more information on genes responsible for resistance mechanism. Nearly, 0.5% and 1.06% genes were hit with the genes involved in defense mechanism and post transcriptional modification respectively. Among these, the most important genes were

**Fig.16 Graphical representation of the EST library generated against *M. eumusae* challenged cv. Manoranjitham**




catalase -2, peroxidase, colletin precursor and calcium-dependent protein kinase 6 (CDPK6). In these four types of genes, only catalase-2 and collectin precursor are found to be involved in the fungal resistance.

## Real Time PCR (RT-PCR) assays

Efforts were undertaken to study the expression profiling of nine randomly selected functionally significant ESTs from SSH library. Using the EST nucleotide sequences, primers were designed using Primer 3 online application in such a way that all the primers would produce amplicons at the size of less than 500bp. The cDNAs obtained from periodical samples of *M. eumusae* challenged cv. Manoranjitham has been subjected to real time PCR assay using SyBrGreen as a fluorescent agent. Samples obtained before infection were used as positive calibrators for reference and target.

In the present study, LUHCN, a *Zea mays* leucine acid dehydrogenase gene was used for normalizing the RT-PCR data and also to calculate the relative quantification ratio. Of the nine primers tested against the cDNA pool of the challenged Manoranjitham cultivar, only eight [2K9USK41 (rca2), 2K9USK227 (CL-46), 2K9USK279 (full

length cDNA clone), 2K9USK28 (cat-2), 2K9USK119 (PsaB), 2K9USK120 (PsaB-2), 2K9USK39 (fba) and 2K9USK21 (pco)] were found to be up regulated (Fig. 17). Among the up regulating genes, 2K9USK28, 2K9USK119, and 2K9USK120 exhibited two fold increase over un-inoculated plants. The gene 2K9USK17 (trpB) only was found to be down regulated by 10 fold lesser than the control. The study showed that the expression of 2K9USK28 and 2K9USK119 genes was maximum at 32hpi, whereas, expression level was maximum at 4hpi for the other three genes (2K9USK41, 2K9USK120 and 2K9USK39). Hence, other ESTs of SSH library which are coding for important functions would be studied by using real time PCR assays.

### Resistant (R) gene expression and isolation studies

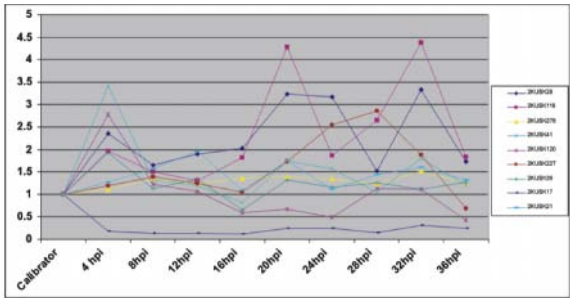



**Fig.17 Relative conc. ratio of some of the SSH library of the cv. Manoranjitham (calculations based on Roche Light Cycler 480)**

Using the database available at the GenBank, important anti fungal gene sequences were obtained and conserved domain were determined using BLAST alignment from the online resources. Primers were designed for the conserved domain of the anti fungal genes namely *Zea mays* anti fungal (Zmaf), *Arabidopsis thaliana* antifungal (Ataf), *Triticum asetivum* protein (Tat1p1), *Zea mays* synthetic Proteinase inhibitor (ZmSPI), *Oryza sativa* β glucanase (OSBG), *Zea mays* Ribosomal Inactivation protein (ZmRIP), *Zea mays* Pathogenesis Related Protein (ZmPR). Leucine acid dehydrogense was used as reference gene for this Real time PCR assays. Expression profiling of the aforesaid genes was studied in *Mycosphaerella eumusae* challenged *Musa* cv. Manoranjitham samples collected at different time intervals (4-36hpi) by using RT-PCR (Roche Thermal Cycler 480).

The RT-PCR results indicated that only OSPRMS, ZMPR, ZMRIP, OSSD, TAT1P1, OST1 and OSCP1 were down regulated when compared to the control gene. Out of five down regulating genes, two genes (OSPRMS and ZMPR) were triggered immediately at 4hpi with *M. eumusae* but from 8hpi, they were not able to produce increased number of transcript copies and were determined as down regulated as compared to control. Though the genus *Oryza* and *Musa* belong to the monocot type and posses many physiological similarities including response to fungal pathogen attack, when compared to the expression level with individual fungal resistant genes, they show different responses for fungal pathogens. Maximum level of expression was noticed at 4hpi for the genes ZMAR and ATAF and it was 24hpi for the genes ATAF and OSBG respectively (Fig.18).

### Resistant gene Isolation

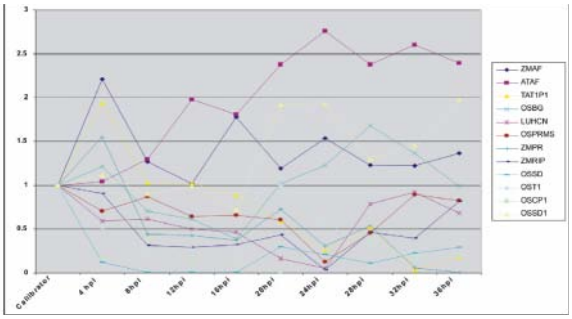



**Fig. 18 Relative quantitation ratio of some of the anti fungal genes tested with the cDNA of cv. Manoranjitham (calculations based on Roche Light Cycler 480)**

An attempt was made to identify and isolate fungal resistant gene from the cDNA pool of *M. acuminata* cv. Manoranjitham. Primers were designed using Primer 3 with the nucleotide sequences obtained from the conserved domain of *Arabidopsis thaliana* anti fungal protein, *Oryza sativa* β-Glucanase (OSBG) & Succinate dehydrogenase, *Zea mays* Pathogenesis related protein and conventional PCR amplification was performed. The resultant amplicons were cloned and sent for sequencing.

## 5.1.8 Identification and characterization of nematode resistance gene (s) in banana

### Sequencing and clustering of SSH clones

SSH library containing 1400 clones were constructed from nematode resistant cultivar Karthobiumtham. From these, 20 clones were sequenced and 456 readable sequences were

obtained. Clustering of the 456 ESTs has allowed construction of an unigene set of 256 unique expression products from *P. coffeae* nematode inoculated *Musa* library. The assembly of sequences produced 188 singletons and the remaining sequences were grouped into 68 contiguous sequences (contigs) (Table 5 ).

**Table : 5 Summary of EST generation and analysis**

| | |
|---|---|
| Total number of clones obtained | 1400 |
| Total no. of clones used for plasmid isolation | 1108 |
| Total no. of plasmids containing inserts | 980 |
| Total no. of plasmids <100bp insert | 180 |
| Total no. of clones sequenced | 520 |
| Total number of readable sequences | 456 |
| Vector sequences | 62 |
| No. of high quality sequences to be deposited at GenBank | 256 |
| Unigenes identified by CAP3 assembly | 256 |
| No. of Unigenes found with no significant | 29 |
| No. of Singlets | 188 |
| No. of Contigs | 68 |
| No. of SSRs | 20 |

## Functional classification of SSH clones

Sequences of suppression subtractive clones have been functionally classified based on the Gene Ontology database. Annotation of the assembled unigene set, through homology searches in the NCBI nucleotide and protein databases revealed that 96.16% of the unigene set hits with known putative functions, the remaining 3.84% of the unigene set hit with expressed proteins, unknown protein, hypothetical proteins, putative proteins, and predicted proteins. Among the functionally classified unigenes, the defense and cell rescue genes constitute the third highest category of functionally classified unigenes and the first two are of energy metabolism and signal transduction.

## Expression profiling of putative genes obtained from SSH

From the SSH library, primers were designed for the putative genes which are hit with some defense related genes for studying the expression profile in both resistant and susceptible cultivars. The expression profiling study carried out using these primers revealed that protease inhibitor gene was expressed only after nematode infestation and the level of expression was declining from 3rd day after nematode inoculation in both resistant and susceptible cultivars (Fig. 19). This showed that this gene is not constitutively expressed but expressed only due to the infestation of nematodes. Whereas metalothionine and glucanase genes were expressed even in both inoculated and uninoculated root. But the level of expression of both the genes was higher in resistant than susceptible cultivar. In general, the transcript level of polyphenol oxidase was increasing up to 6 DAI of nematode than the uninoculated plants. This confirmed that PPO, protease inhibitor gene, glucanase and methalothionine are upregulated owing to *P. coffeae* infestation.

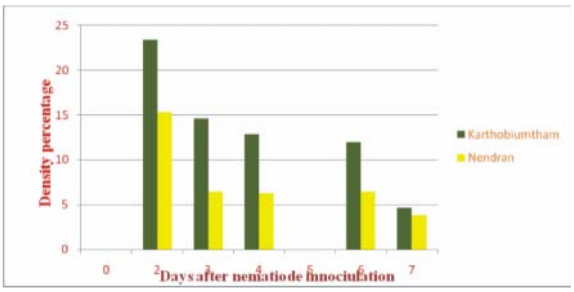



**Fig. 19. Transcript level of Protease inhibitor**

## Expression study of resistance gene analogues

A total of 76 RGAs were isolated from *P. coffeae* resistant cultivar Karthobiumtham and out of which, only 20 RGAs were uninterrupted sequences. Neighbor joining analysis of the uninterrupted RGA sequences of nematode resistant cultivar Karthobiumtham grouped the 20 RGAs into six clades. RGA specific primers were designed from each clade and found that all the primers were amplified in the gDNA of *Musa* accessions. To know the transcript level of these RGAs in resistant and susceptible cultivars, cDNA of these cultivars were used as template to amplify these RGAs. The results revealed that all the RGAs were amplified in both resistant (Karthobiumtham) and susceptible cultivars (Nendran) except C6 RGA in Nendran (Fig.20). These results suggested that all these primers were expressed constitutively in both cultivars except C6 in Nendran

## Development of CAP markers from *Musa* RGAs.

All the six RGA primers, which have been designed from each clade of uninterrupted

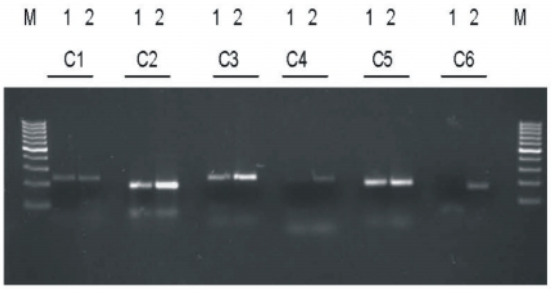



**Fig. 20. I Expression profile of RGAs in 1) cv. Karthobiumtham and 2) Nendran. C1-C6 - Specific primers developed from each RGA family.**

sequences were used for amplifying different accessions and showed monomorphic banding pattern. Hence, these amplified products were digested with different cutters enzyme and the result of this RFLP analysis showed polymorphic bands between accessions (Fig. 21). Hence, these primer and enzyme combinations used in this study could be used as CAP markers in identifying the resistance genes as well as to obtain high resolution linkage map.

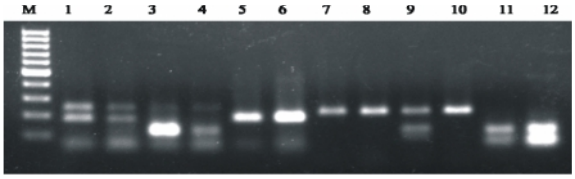



**Fig. 21. Restriction digestion of PCR products obtained from RGA specific primers**

| Lane | Accessions | Primers | Restriction enzyme |
|---|---|---|---|
| 1, 2 | Calcutta 4, Phrimawild | C1 | Rsa 1 |
| 3, 4 | Calcutta 4, Phrimawild | C1 | Taq 1 |
| 5, 6 | Calcutta 4, Phrimawild | C2 | Rsa 1 |
| 7, 8 | Karthobiumthum, Nendran | C4 | Taq 1 |
| 9, 10 | Matti, Cultivar rose | C4 | Taq 1 |
| 11,12 | Karpuravalli, Pisang jajee | C6 | Taq 1 |

## Mining of EST database for developing SSR markers and validation

Banana ESTs downloaded from NCBI were trimmed by using the trimmest. These were grouped by using CAP3 analysis and all the singlets and contigs were analysed for designing SSR primers. Totally, 2247 SSRs were identified out of which, maximum number of SSR was obtained for tri repeats in both singlets and contigs. A total of 13 EST SSR primers were synthesised and validated in the *Musa* gDNA. Except four primers, all the other primers had amplification. Out of nine SSR primers, six primers showed polymorphism among 13 *Musa* accessions (Fig. 22). But the size of the SSR2 primer generated amplicon was more than expected size which suggested that these primers have amplified the intron region which was present in gDNA. This would be further confirmed by sequencing.

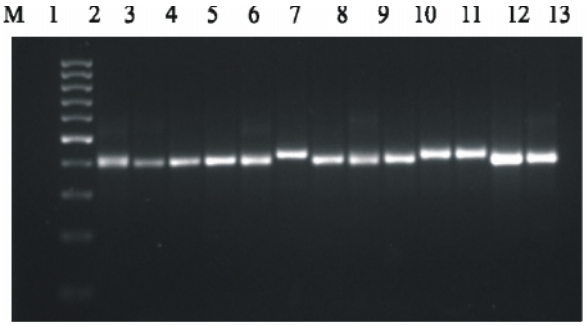



**Fig.22 Polymorhpism among *Musa* accessions by using SSR primer 4**

M- Marker
1- Karthobiumtham
2- Nendhran .
3- Matti
4- Cv.rose
5- Calcutta 4
6- Phirima wild
7- Pisang jajee
8- Karpuravalli
9- Pisang linin
10- Bhim kol
11- Attiakol
12- Kanai bansi
13- FIHA 1

## 5.2 CROP PRODUCTION

### 5.2.1 Standardization of agro techniques for banana production and productivity

#### Experiment on "Standardization of spacing and nutrient requirement for banana cv. Udhayam (ABB)"

During the reporting period observations were recorded on the fruit quality parameters as influenced by different spacing and levels of N&K fertilization in plant crop.

#### Effect on fruit quality

The fruit TSS and fruit acidity under different treatments were in the range of 24.3-29.4° B and 0.39-0.61 % respectively. The fruit from the widest spacing (21X2.4m) recorded the highest TSS (27.71° B) and lowest fruit acidity (0.49%) (Fig.23). Among the fertilizer doses, the plants applied with 300:400g N&K plant$^{-1}$ recorded the lowest fruit acidity of 0.45%. The pulp: peel ratio was the highest (6.69) in treatments with wider spacing (2.1 X 2.4m) and with fertilizer dose of 300:400g N&K fertilizer application while the lowest pulp: peel ratio (5.28) was in plants at the closest spacing the with lowest fertilizer dose.

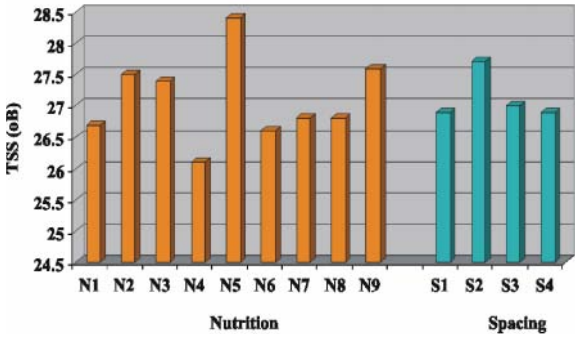



**Fig. 23 Effect of spacing and nutrition on fruit TSS in Udhyam (Plant crop)**

#### Effect on nematode infestation

Analysis of the soil and root samples revealed that the population of *M. incognita* was found maximum in both soil (275/250g soil) and root (460/10g root) samples from 1.8 X 1.8m spacing and 200:300g N&K plant$^{-1}$. The least nematode population of only 32.3/250g of soil was observed at the widest spacing of 2.1 X 2.4m. Among the fertilizer doses, the highest population of 179.3 was recorded in plants that received the lowest fertilizer and decreased (65.0/g root) with the increasing fertilizer doses (Fig.24 ).

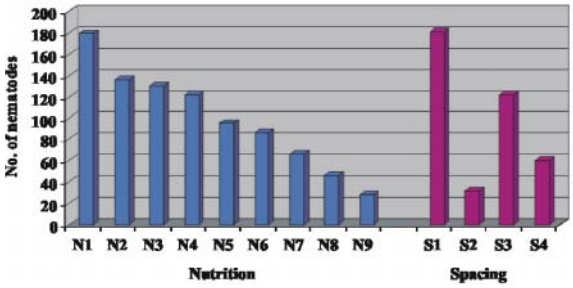



**Fig. 24 Effect of spacing and nutrition on nematode population in the soil in Udhayam**

#### Effect on the first ratoon crop

In ratoon crop, the plants at wider spacing of 2.1 X 2.4m recorded the shortest plants with more plant girth and retained more number of healthy leaves (14.3). Where as, the plants at the closest spacing of 1.8 X 1.8m recorded the tallest plants with least plant girth, least number of healthy leaves and total leaf area (Fig.25 a&b). In general, the plants under the wider spacing have exhibited early flowering as compared to the closer spacing.

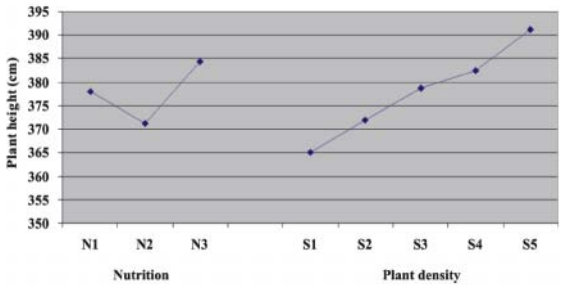



**Fig. 25(a) Efect of plant density and nutrtion on plant height in Udhayam**

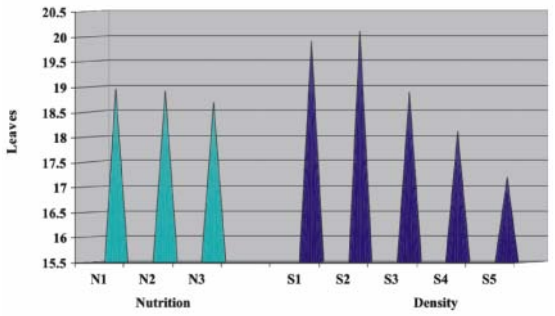



**Fig. 25(b) Efect of plant density and nutrtion of healthy leaves in Udhayam**

#### Studies on the effect of organics on the BSV and BBMV infected Poovan banana

A new experiment was laid out to study the effect of organics on BSV and BBMV infected Poovan banana. Poovan banana plants infected with BSV and BBMV were selected and planted. Healthy plants were kept as control. Totally, six different sources of nutrients were imposed.

Significant differences were recorded among three different planting materials and sources of nutrients.

The plants infected with Banana Bract Mosaic Virus (BBMV) exhibited stunted plant growth with the lowest plant height (1.89m), pseudostem circumference (0.53m), number of healthy leaves (14.0), leaf length (1.54m) and breadth (0.66m) and mean leaf area (0.84 m2) as compared to BSV infected and healthy Poovan banana plants. The plants applied with 100 % RDF or 125 % RDF as inorganic sources were more vigorous with tall and robust plants, more number of healthy leaves and larger leaf area (Fig.26 a&b).

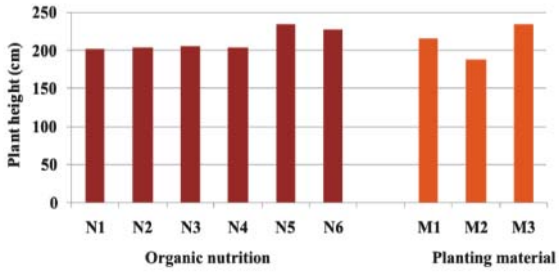



**Fig. 26(a) Effect of organics on plant height in BSV and BBMV infected Poovan**

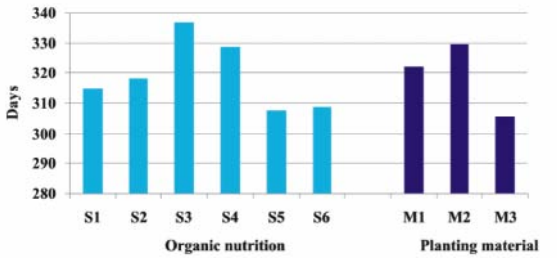



**Fig. 26(b) Effect of organics on flowering in BSV and BBMV infected Poovan**

## 5.2.2 Studies on micronutrients in Banana

### Effect of micronutrients with and without sulphur application on banana under high pH soil

Application of sulphur in Ney Poovan banana reduced the rhizosphere soil pH from 8.6 to 7.8, which facilitated the availability of micronutrients applied to soil and increased the plant growth parameters like plant height, pseudostem girth, total number of leaves and total leaf area significantly over the control, by 12.5, 5.72, 4.96 and 4.16 %, respectively. Sulphur application also increased the yield parameters like number of fruits per bunch and bunch weight significantly over control by 2.20 and 13.72 %, respectively. The leaf nutrient concentrations like N, P, K, Ca, Mg and S also increased significantly due to sulphur application over control by 1.99, 7.62, 7.40, 43.90, 27.44 and 73.29%, respectively. The individual effect of different micronutrients with respect to different mode of applications on bunch weight is given in Fig. 27.

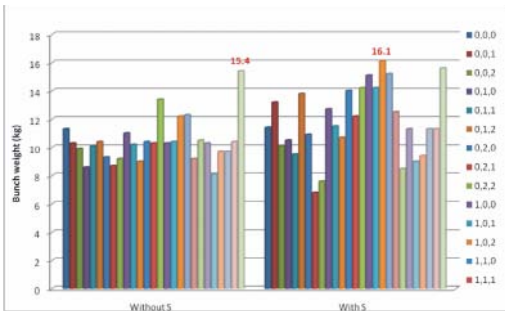



**Fig. 27 Effect of micronutrients on bunch weight**

Foliar application of 0.5% solution each of $FeSO_4$, $ZnSO_4$ and Borax without sulphur recorded the highest bunch weight of 15.4 kg (36.3% more than control) with net additional profit of Rs.61750 per ha. Soil application of 5g $FeSO_4$ per plant and foliar application of 0.5% solution each of $ZnSO_4$ and Borax with sulphur recorded the highest bunch weight of 16.1 kg (41.2% more than control) with net additional profit of Rs.69750 per ha. The highest correlation of 0.55** was observed between leaf K concentration with sulphur application and bunch weight. The leaf S content with sulphur application recorded the highest correlation of 0.436** with bunch weight (Table 6).

**Table 6. Correlation coefficients (r) between plant growth yield parameters and leaf nutrient concentrations**

| | Leaf N% | | Leaf P% | | Leaf K% | | Leaf S% | |
|---|---|---|---|---|---|---|---|---|
| | -S | +S | -S | +S | -S | +S | -S | +S |
| Plant height | -0.037 | 0.570** | -0.182 | -0.309* | -0.031 | 0.327* | -0.049 | 0.382* |
| stem girth | 0.048 | 0.413** | 0.018 | -0.077 | 0.106 | 0.287* | 0.155 | 0.251* |
| Total number of leaves | 0.383* | 0.417** | 0.168 | 0.121 | 0.636** | 0.570** | 0.168 | 0.454** |
| Total leaf area | 0.046 | 0.304* | 0.060 | 0.266* | 0.207* | 0.490** | -0.001 | 0.330* |
| Number of fingers | 0.342* | 0.066 | 0.214 | 0.281* | 0.493** | 0.282* | 0.390* | 0.541** |
| Bunch weight | 0.208* | 0.209* | 0.185 | 0.266* | 0.353* | 0.550** | -0.019 | 0.436** |

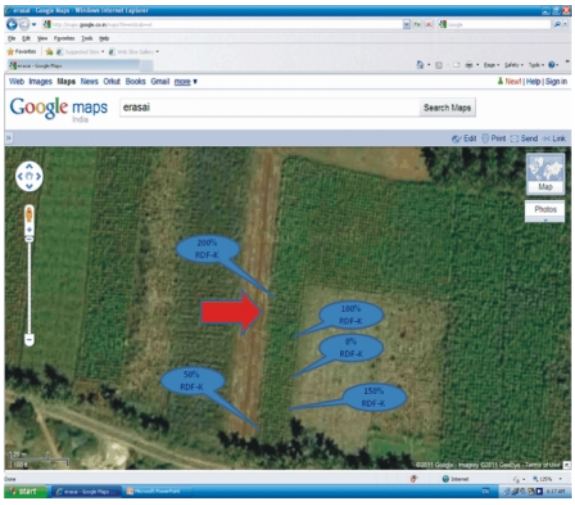
*Significant at 5% level and **Significant at 1% level

### Development of Fertilizer Adjustment Equations in Banana

Planting of Grand Nain was taken up in farmer's field at Erasakkanayakkanur (near Chinnamanur), Theni Dt., Tamil Nadu on 2011. The fertiliser treatment combinations were imposed in factorial RBD (replicate thrice), which includes 4 levels of N (N0, N50, N100 and N150), 3 levels of P (P0, P50 and P100) and 5 levels of K (K0, K50, K100, K150 and K200), where recommended levels of NPK is 200:50:400 g NPK/plant. The whole set of these treatment combinations were imposed in each of two blocks, one without organic manure and other with organic manure. The fertilizer treatment combinations from 4 X 3 X 5 levels of N, P and K including absolute controls were randomly allotted in each of the four strips and Tissue culture plants of Grand Nain banana were planted.

At 5 months after planting (MAP ), the average height of the plants in the organic manure applied block was greater than without organic manure application. The pseudostem girth significantly varied with graded levels of N, P and K. The highest mean pseudostem girths of 74.3cm at N100, 74.2cm at P0 and 76.4cm at K50 were observed. The variations in total number of leaves were non-significant in blocks with and without organic manure application. But, the graded levels of N, P and K significantly influenced the number of leaves. The highest number of leaves (19.4) was observed at K200 followed by K50. A google satellite view of the experimental field at Erasakkanayakkanur, showing canopy density variation due to graded levels of potassium application (Fig.28).

Fig.28 Satellite view of experimental field




## 5.3. CROP PHYSIOLOGY, BIO CHEMISTRY AND POSTHARVEST TECHNOLOGY

### 5.3.1. Crop Physiology

### Physiological growth analysis of banana

Popular banana cultivars such as Ney Poovan, Poovan and Karpuravalli were studied for physiological growth analysis. The results of the analysis indicated that from third to sixth months, the average leaf production recorded was 4.32 leaves /month and the Leaf Area Index increased from 0.36 at 3rd month to 1.42 at sixth month. The leaf emergence rate was 1.02 leaves/week. The number of days taken for flowering was 285 days for Ney Poovan, 297 days for Poovan and 308 days for Karpuravalli. The number of hands varied from 9 -13 and days taken to open hand was 5 to 13 days for Karpuravalli.

### Drought stress tolerance in banana

Standardization of total soluble solids (TSS) as indirect means of measuring osmotic potential of banana cell sap was carried out under soil moisture stress condition. The plant sap osmotic potential (OP) and TSS of plant sap positively correlated, when the OP was up to < 0.3 Mpa. However, when the OP exceeds > -0.3Mpa, the TSS value was not correlated. Besides, the TSS value was not the same, when the OP of the same value recorded in different genotypes. It was observed that under soil moisture stress, the *in vivo* nitrate reductase activity was higher in Karpuravalli and Poovan cultivars (>0.246 mg of $KNO_3$ conversion / g fr.wt.) when compared to other cultivars such as Robusta, Nendran and Karpuravalli (<0.104 mg of $KNO_3$ conversion/g fr. wt.).

### Biochemical analysis of plant sap

The plant sap of Poovan, Saba and Karpuravalli were analyzed when the soil moisture matrix potential reached about -0.6MPa. Saba and Poovan bananas accumulated more free amino acids (12.52 and13.27mg / ml of plant sap, respectively) than Karpuravalli (9.03 mg / ml plant sap). The sugar content recorded was in the range of 4 .03 to 5.23 mg / ml plant sap.

## 5.3.2. Biochemistry

### Studies on biochemical mechanism of resistance of bananas to *Pratylenchus coffeae*

The assaying of activities of phenol oxidizing enzymes viz., peroxidase and polyphenol oxidase; stress related enzyme, phenylalanine ammonia lyase; lignin synthesizing enzyme, cinnamyl alcohol dehydrogenase and estimation of contents of total phenols, lignin and tannins were analyzed in the roots of resistant banana varieties viz., Anaikomban and Yangambi Km5 and susceptible varieties viz., Nendran and Robusta at 90, 120, 150 and 180 days after inoculation of the root lesion nematode, *Pratylenchus coffeae*, from both inoculated and uninoculated control plants.

### Phenol oxidizing enzymes

The analysis indicated that the phenol metabolizing enzymes activity showed decreasing trend from 90 days to 180 days. At 120 days after inoculation, the average activity of peroxidase was 83 nanokatals/mg protein in resistant varieties and 27 nanokatals in susceptible varieties and at 180 days, the average activities of the enzyme were 72 and 25 nanokatals/mg protein respectively in resistant and susceptible varieties. The mean activity of polyphenol oxidase at 120 days was 80 nanokatals/mg protein and 46 nanokatals and at 180 days after, the activities of PPO were 48 and 42 nanokatals in resistant and susceptible bananas respectively. However, the activity levels of these enzymes at 180 days were higher than the constitutive levels and the average activities of the enzymes were many-times higher in resistant varieties than in susceptible cultivars (Fig.29).

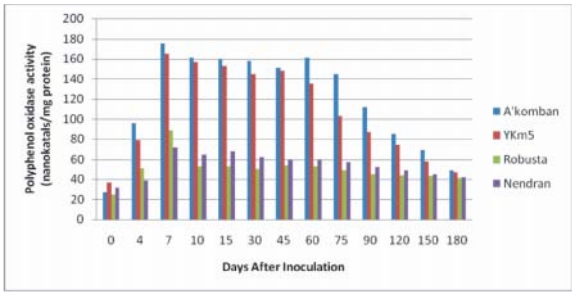



**Fig. 29. The effect of *Pratylenchus coffeae* infestation on polyphenol oxidase activity in roots of banana cultivars**

### Stress related enzymes

The activity of Phenylalanine Ammonia Lyase (PAL) also decreased from 90 days to 180 days of observations. At 120 days, the mean activity of PAL was 74 picokatals and 32 picokatals/mg proteins in resistant and susceptible bananas respectively. Similar to phenol-metabolizing enzymes, the levels of PAL activity was higher than the constitutive levels detected in the roots of banana. In general, the activity levels of this enzyme were also higher in resistant varieties than in susceptible cvs. at 180 days.

### Lignin synthesizing enzymes

Cinnamyl Alcohol Dehydrogenase (CAD) activity too decreased from 90 days to 180 days of observation. At 90$^{th}$ day, the CAD activity was 156 picokatals/mg protein in resistant bananas and 43 picokatals in susceptible bananas and at 120 days, the activity was 144 and 40 picokatals in resistant and susceptible bananas respectively (Fig.30). It is very obvious that the induction levels of this enzyme in resistant varieties was higher than in susceptible varieties and the levels of activity of the enzyme at 180 days after inoculation were higher than the constitutive levels.

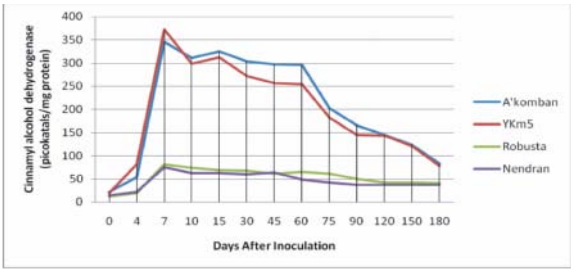



**Fig. 30. The effect of Pratylenchus coffeae infestation on cinnamyl alcohol dehydrogenase activity in roots of banana cultivars**

### Phenolic content

The total soluble phenolics contents of the resistant and susceptible bananas were found decreasing from 90 to 180 days after root lesion nematode inoculation but the content of phenols was higher in resistant bananas. At 120 days the mean concentration of total phenol was higher (0.129 mg/g tissue) in resistant varieties compared to susceptible varieties (0.071 mg/g tissue). (Fig.31). It is clear from the study that the contents of total phenols were higher in resistant bananas

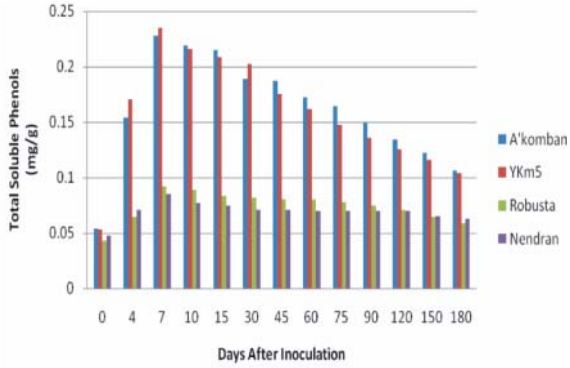



**Fig. 31.The accumulation of total soluble phenols in roots of banana cultivars following infestation of *Pratylenchus coffeae***

than in susceptible bananas and the amount of phenols in inoculated roots was many times higher than in uninoculated controls. The contents of phenols at 180 days were also higher than in pre-inoculation constitutive levels.

Free soluble phenolic and cell wall-bound phenolic compounds were extracted from the roots of resistant and susceptible banana cultivars at seven days after root lesion nematode inoculation and analyzed by Reverse Phase High Performance Liquid Chromatography. The results revealed that presence of six major methanol soluble phenolic metabolites and four major cell wall-bound phenolic metabolites in both resistant and susceptible banana cultivars. Quantitatively, the contents of free-soluble and cell wall bound individual phenolic metabolites were higher in resistant cultivars than in susceptible cultivars. The concentrations of phenolic metabolites in roots of nematode-inoculated resistant and susceptible banana varieties were higher than in roots of uninoculated banana at 7 days after root lesion nematode inoculation indicating the synthesis of more metabolites due to infection by the nematode. Compared to free-soluble phenolic compounds, the amount of cell wall-bound phenolic metabolites were relatively more both in resistant and susceptible varieties.

## Lignin and Tannin contents

To commensurate with the activity of cinnamyl alcohol dehydrogenase activity, the lignin synthesis was also decreased from 90 days to 180 days and the lignin contents in both resistant and susceptible bananas were higher in inoculated plant roots than in uninoculated control roots (Fig. 32).

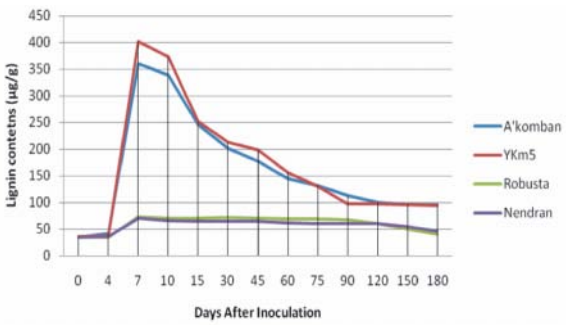



**Fig. 32. The accumulation of lignin in roots of banana cultivars following infestation of *Pratylenchus coffeae***

The hydrolysable tannins decreased slowly from 90 days to 180 days but the level of tannins were higher in resistant bananas than in susceptible cultivars. At 90$^{th}$ day, the total tannin contents were 83 µg/g in resistant varieties and 42 µg/g in susceptible cultivars. At 180 days, the total tannins were 54 and 33 µg in resistant and susceptible bananas respectively indicating that the total hydrolysable tannins were higher in resistant banana varieties than in susceptible cultivars and also higher in nematode-inoculated roots than in un-inoculated roots.

Similar to total hydrolysable tannins, the contents of condensed tannins and proantho cyanidins also showed decreasing trend from 90 to 180 days after inoculation of the nematode, but higher levels in resistant varieties (Anaikomban and Yangambi km5). At 90$^{th}$ day, the proantho cyanidins contents in resistant bananas was 0.389 (A550) and 0.283 (A550) in susceptible varieties. The same trend was also observed till 180 days after nematode inoculation. The contents of condensed tannins were higher in resistant bananas than in susceptible bananas and higher in inoculated roots than in un-inoculated roots.

The proanthocynidin compounds from roots of resistant and susceptible cultivars at seven days after nematode inoculation was extracted using butanol-HCl and analyzed by RP-HPLC. The analysis showed that root contained seven major proanthocyanidin compounds both in resistant and susceptible bananas. The amounts of individual proanthocyanidins extracted from the roots at seven days after nematode inoculation were higher in resistant varieties than in susceptible varieties.

## 5.3.3. Postharvest Technology

### Evaluation of different varieties of bananas for fibre extraction

Evaluation of different varieties of bananas for fibre extraction was carried out in collaboration with eight coordinating/optional centers under AICRP on Tropical Fruits, IIHR (ICAR), Bangalore. The biochemical composition of the banana fibre (BCKV, Mohanpur) extracted by alkali treatment and hand extraction was studied. Among the treatments, the highest cellulose content (58.0%) in the fibre was recorded with 0.1% NaOH treatment in cv. Grand Naine, while it was the highest (56.33%) in the hand extracted fibre in cv.'Martman' and the same treatment also registered the lowest pectin content (0.61%) (Table 7) . For Nendran banana (BRS, Kannara), the fibre extracted by 0.5% alkali treatment contained the highest cellulose content (64.0%), followed by 1.0% alkali (63.30%), which was on par. Moreover, the lowest pectin content (0.37%) was registered with 1.0% alkali treatment (Table 8).

### Comparative evaluation of banana - Flower, fruit, stem and peel pickles

Comparative quality analysis of fresh samples was carried out in four types of banana based pickles. Moisture content varied from 34 (fruit pickle) to 57% (peel pickle), oil content from 20 (peel pickle) to 31% (flower pickle), crude fibre from 4 (peel pickle) to 9% (stem pickle) and total chlorides varied (on dry wt. basis) from 6 (fruit pickle) to 10% (peel pickle). Both peel and flower pickles (thokku) scored as moderate under organoleptic evaluation. After two months of storage, of the four types of pickles compared, stem pickle with high fibre content (7.8%) was accepted. However, peel pickle was accepted under organoleptic sensory evaluation with less oil content (21%) after four months of storage (Fig.33).

### Refinement and re-evaluation of 'Sip-up'

A new product, banana pulp based 'Sip-up' was prepared with and without pasteurization and stored at 0°C in which without pasteurization has been accepted moderately. This was refined

**Table 7. Chemical properties of fibres extracted by various extraction processes in banana varieties(Centre: Mohanpur, BCKV)**

| Variety | Treatments | Cellulose (%) | Pectin (%) | Lignin(%) |
|---|---|---|---|---|
| Grand Nain | 0.1% NaOH | 58.00 | 0.74 | 19.25 |
| | 0.5% NaOH | 55.66 | 1.04 | 19.15 |
| | 1% NaOH | 42.66 | 0.84 | 18.40 |
| | Hand extraction | 53.00 | 0.87 | 18.55 |
| Martman | 0.1% NaOH | 45.00 | 0.97 | 17.05 |
| | 0.5% NaOH | 50.66 | 0.67 | 20.05 |
| | 1% NaOH | 43.66 | 0.95 | 17.80 |
| | Hand extraction | 56.33 | 0.61 | 14.75 |

Values are the mean of three replications.

**Table 8. Chemical properties of fibres extracted by various extraction processes in banana variety (Centre: *Kannara, KAU*)**

| Variety | Treatments | Cellulose (%) | Pectin (%) | Lignin(%) |
|---|---|---|---|---|
| Nendran | 0.1% NaOH | 62.00 | 0.395 | 16.75 |
| | 0.5% NaOH | 64.00 | 0.426 | 15.20 |
| | 1.0% NaOH | 63.30 | 0.370 | 16.75 |
| | Machine extraction | 49.00 | 1.066 | 12.20 |
| | Hand extraction | 48.00 | 0.870 | 11.20 |

Values are mean of three replications.

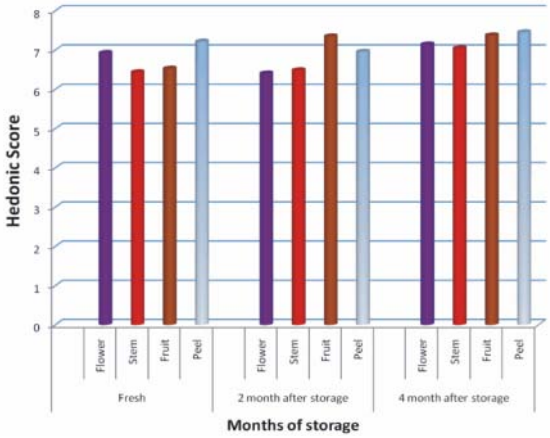



**Fig. 33 : Sensory evaluation of banana based pickles**

with condensed milk and ginger for improving the flavour and consistency. The product was stored up to 15 days at 0°C, which has been accepted under organoleptic evaluation.

## Identification of banana varieties with low sugar and carbohydrate in banana

Twelve commercially cultivated varieties of banana were evaluated for physio-chemical parameters in order to identify variety with low sugar and carbohydrate. The analysis indicated that total carbohydrate content varied from 9.60% (Robusta) to 24.4% (Nendran) and total sugars from 15.46% (Grand Nain) to 23.86% (Nendran). Among the varieties, Grand Nain and Robusta were identified for low sugar and carbohydrate content respectively. The other parameters of the varieties are pulp-peel ratio: 1.885 and 1.696; TSS: 19.2 and 20°Brix; acidity: 0.276 and 0.404%; moisture: 78.09 and 72.09; Vit.-C: 1.623 and 1.313 mg/100g for Robusta and Grand Nain respectively.

## Evaluation of different varieties of bananas for fibre extraction

The biochemical parameters analysed for banana fibre extracted by various processes are provided in Table 7&8. For Nendran banana, the fibre extracted by 0.5% alkali treatment contained highest cellulose content (64.0%), followed by 1.0% alkali (63.30%), which may be on par with each other. Moreover, the lowest pectin content (0.37%) was registered with 1.0% alkali treatment.

## 5.4. CROP PROTECTION

### 5.4.1. Nematode Management

#### Validation of bioagents for the control of root-knot nematode in Udhayam banana

The effect of application of certain bioagents such as *Trichoderma* spp. *Pseudomonas* spp. and *Pacilomyces* spp. along with neem cake was assessed under micro plot condition in cv.Udhayam. These bio-agents and neem cake were applied 20g and 500g respectively. The results revealed that the combined application of bioagents and neem cake showed steady increase of plant growth at 6th, 9th and 12th months after planting with significant reduction in root-knot nematode population. However, among the treatments, *P.lilacinus*+neem cake, *T.viride*+neem cake and nematicide (carbofuran) were found to be superior recording the maximum plant growth and yield with significant reduction in nematode populations compared to untreated control plants(Table 9).

Karpuravalli at different intensities (100 to 550/g root) whereas, the root knot nematode, *Meloidogyne incognita* was maximum in cv.Karpuravalli (350/g root) followed by cv. Ney Poovan (85/g root). Severe infestation of root-knot (Fig.) and root-lesion nematodes (> 100/g root) was recorded in cv. Grand Nain at Theni district of Tamil Nadu (Fig. 34).

**Fig. 34 Root-knot infested Grand Naine banana roots**

**Table 9. Effect of bio-agents on the control of root-knot nematode in cv.Udhayam under micro plot condition.**

| Treatments | Vegetative stage (March) | Flowering stage (September) | Harvesting stage (December) |
|---|---|---|---|
| *P.lilacinus* + Neem cake | 220 | 145 | 60 |
| | (30.0) | (54.0) | (83.8) |
| *T.viride* + Neem cake | 250 | 175 | 90 |
| | (18.0) | (44.5) | (75.7) |
| *T.harzianum* + Neem cake | 195 | 155 | 120 |
| | (36.0) | (50.8) | (67.6) |
| *P.fluorescens* + Neem cake | 255 | 200 | 135 |
| | (16.4) | (36.6) | (63.6) |
| Carbofuran @ 30g/plant | 215 | 155 | 75 |
| | (29.6) | (50.8) | (79.8) |
| Tagetus (inside of ring) | 245 | 165 | 95 |
| | (19.7) | (47.7) | (74.4) |
| Control | 305 | 315 | 370 |

Figures in parenthesis are the percentage reduction of nematodes over control.

#### Identification of nematode problems in Tamil Nadu

Survey was carried out in Karur and Theni districts of Tamil Nadu for nematode incidence in different varieties of banana. The results revealed that the root-lesion nematode, *Pratylenchus coffeae* was most predominant and found to infest the cultivars like Nendran, Ney poovan and

#### Seasonal influence on the effect of bio-control agents in controlling nematode population in ratoon crop cv. Ney Poovan

Nematode populations of soil and root were assessed at monthly interval in ratoon crop of Ney Poovan applied with different biocontrol agents. The results showed that significant reduction in root knot nematode populations (< 45 nematodes/

g root) was observed from April to December, 2010 in all the treatments viz. VAM alone, VAM + *Trichoderma viride*, VAM + Azospirillum, VAM + Phosphobacteria. In untreated check, the nematode population recorded was 55 and 70 / g root in the month of April and May respectively which, reduced to 35 and 40 in June and July respectively. However, the population increased slowly and reached the maximum of 116,125 and 142/ g root in the month of October, November and December respectively.

### Comparative efficacy of *Bacillus subtilis* and *B.cereus* against root lesion nematode in banana cv. Ney Poovan

Individual and interactive effect of *Bacillus subtilis* and *B. cereus* was studied in pots under net house condition against root-lesion nematode in cv. Ney Poovan, 60% increase in plant growth with 90% reduction in nematode populations was recorded in the combined application of *B.subtilis* and *B.cereus* than individual treatments.

### Integrated approach for the management of major nematodes in banana cv. Udhayam

A field trial was laid out in August, 2010 for evaluating bio agents, chemical pesticides and cultural practices for the management of nematodes in cv.Udhayam banana. Nematode population was assessed prior to the treatment at 3rd and 6th month after planting. Significant reduction and steady decrease in nematode population (>65%) with increased plant growth (>40%) was recorded in plants treated with four treatments viz., NRCB Nemacinus (*P. linacinus*) + Neem cake 250g / plant; NRCB Nemacens (*P.flourescens*) + Neem cake 250g / plant + Marigold intercrop + *P. linacinus* + *P.flourescens* + Neem cake and Marigold intercrop with VAM (*Glomus fasciculatum* +*G. mosseae*) compared to the control and other treatment plants.

### Identification of principle compounds from the promising botanical for the control of nematode

The green leaves of *Datura stromanium* and *Calotropis gigantea* were collected, dried and petroleum ether diethyl ether solvent extract was prepared. Five different fractions received from biochemist were tested for their nematicidal activity against root lesion and root-knot nematodes under *in vitro* conditions. The results showed that E1 and E2 fractions of *Datura stromanium* exhibited 60 % and 30 % mortality of root-lesion and root-knot nematodes respectively when exposed to 72h at 50% conc. whereas, E2, E3 and E5 fractions of *C. gigantea* exhibited 100 % and 70 % mortality of root lesion and root knot nematodes respectively when exposed to 48h at 50% conc.

### Screening of *Musa* germplasms against major nematodes

Out of 52 core collection of *Musa* germplasms screened against root lesion and root knot nematodes separately in pots under shade net condition resulted 5 diploids (Kunnan, Borkal baista, Gragric sarpara, Elavazhai and *Musa* ssp. *burmanica*) and 8 triploids (Dasaman, Chirapunji, Kalibow, Amrithapani, Terabun, Thenkadali, Ladan and Ennabenian) were resistant to both the nematodes. Individual nematode performance revealed that 3 diploids (Agniswar, Narmine and Andaman balbisiana); 2 triploids (Bungan and H-3) and one hybrid (H-201) were found resistant to root lesion nematode *(P. coffeae)* whereas 5 diploids and 15 triploids were found resistant to root-knot nematode (*M. incognita).*

## 5.4.2. Management of Banana Weevils

### Refinement of methodology for isolation and characterization of terpenoid compounds present in banana corm and leaf sheath

Volatiles from leaf sheath were collected by three different methods viz., solvent extraction, microwave assisted extraction and air entrainment method and evaluated against banana corm weevil, *Cosmopolites sordidus*. The results indicated that the solvent extraction of banana leaf sheath attracted maximum weevils than the corm. Maximum weevil attraction of 48.0 % was recorded in cv.Nendran followed by microwave extraction and air -entrainment method (Table 10).

### Characterization of terpenoid components of corm and bioassay of corm volatiles

Volatiles from corm and leaf sheath of cvs. Poovan, Nendran and Karpuravalli bananas were extracted by three different methods viz., solvent extraction; microwave assisted extraction and air entrainment methods. Gas chromatography was performed for identification of volatile components present in cv. Karpuravalli. The result showed that,

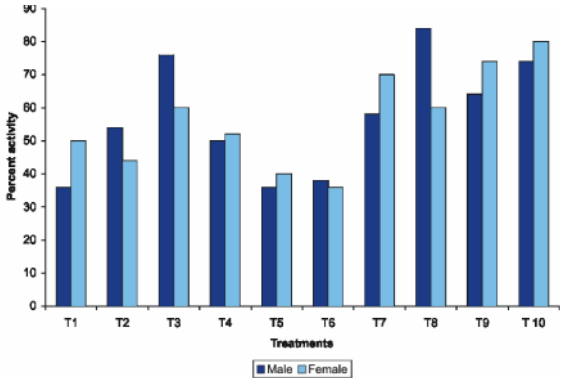
**Table 10. Volatiles collected by different methods from two cultivars and their response to Banana corm weevil**

| Method of collection Material | Host (cv.Nendran) Banana corm | Host (cv.Nendran) Banana leaf sheath | Host (cv.Poovan) Banana corm | Host (cv.Poovan) Banana leaf sheath |
|---|---|---|---|---|
| Solvent Extraction | 41.42a (39.984) | 48.00a (43.847) | 36.00 a (36.772) | 38.00 a (36.698 ) |
| Microwave assisited extraction | 18.57b (25.191) | 20.00b (25.971) | 18.00 b (24.939) | 12.00 b (20.07) |
| Air entrainment method. | 30.00ab (32.907) | 30.00ab (32.961) | 24.00 ab (29.232) | 30.00 a (33.086) |
| Control (Air) | 7.14 c (13.986) | 2.00 c (5.979) | 10.00 b (16.947) | 12.00 b (20.06) |
| CD (0.05) | 8.4709 | 10.1557 | 8.760 | 5.750 |

maximum volatile components were extracted by the solvent extraction method. A total of 15 and 10 volatile components were extracted the dimethylene chloride and hexane solvents from cultivar Karpuravalli and the retention time (RT) values ranged from 35.023 to 65.206 and 3.093 to 47.839 respectively in dimethylene chloride and hexane solvents (Fig. 35).

Extracts from corm and leaf sheaths of eight banana cultivars using dimethylene chloride as solvent was studied by four way olfactometer. The results indicated that, the corm and leaf sheath extract of Karpuravalli recorded the maximum attraction of 44.0% and 38.0% respectively. The attraction was very less in leaf sheath of cv.Virupakshi. (Table 10 & 11).

**Fig. 35 Olfactometry of Sc.No.1 and other extracts against banana stem weevil (Percent activity)**




$T_1$- Male extract ; $T_2$-Female extract vs Hexane ; $T_3$-Host extract ; $T_4$- Sc.No.1 ; $T_5$- Male extracxt + Host extract + Sc.No.1 ; $T_6$- Female extract + Host extract ; $T_7$- Male extract + Hosta extract ; $T_8$- Female extract+ host extract + Sc.No.1 ; $T_9$- Sc.No.1 + Host extract ; $T_{10}$- Banana tissue.

**Table 11. Evaluation of solvent extracts of host plant to corm weevil by four way olfactometer**

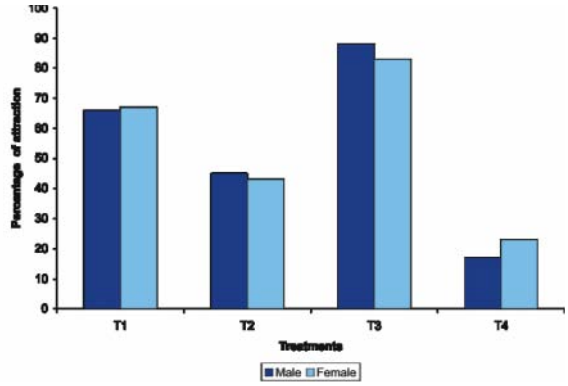
| Solvent extracts of cultivars | Per cent weevil attraction Banana leaf sheath | Banana corm |
|---|---|---|
| Ney Poovan | 22.0 (27.008) | 22.00 bc (27.175) |
| Poovan | 26.0 (29.958) | 20.0 bc 26.268) |
| Saba | 26.0 (28.170) | 14.0 bc (19.902) |
| Monthan | 18.0 (22.260) | 42.0 a (39.863) |
| Virupakshi | 10.0 (15.459) | 28.0 c (31.756) |
| Red Banana | 30.0 (32.664) | 18.0 ab (24.642) |
| Karpuravalli | 38.0 (37.977) | 44.0 bc (41.313) |
| Robusta | 20.0 (24.358) | 10.0 c (18.435) |
| Control | 08.0 (3.833) | 2.0 d (5.979) |
| CD (0.05) | NS | 11.959 ** |
| SEd | 7.781 | 5.871 |

## Collection and bioassay of stem weevil released volatiles and selected semiochemicals

Volatiles released by male and female stem weevils were collected by air entrainment method and host plant extract was collected by solvent extraction method. These volatiles and extracts were subjected to behavioral and electro physiological assays and the response was recorded in percentage of weevil attraction and milli volts (m V) by Electro Antenno Graph (EAG) respectively.

The result of the electrophysiological assays showed that the EAG value for the male extract + host plant volatile extract of susceptible cultivar was 8.262 mV. The host plant volatile extract of susceptible cultivar indicated a maximum response of 7.644 mV to male weevils, 4.445 mV to female weevils. Semiochemical No.1 alone evoked a low response of 1.679 m V to males and a medium response of 4.445 m V to female weevils (Table). Based on the results obtained from electro physiological studies, olfactometric study was conducted. A maximum percent of weevil attraction was recorded in semiochemical No.1 + host plant volatile extract of susceptible cultivar to male and female weevils of *O. longicollis.* Weevil response of 84.0 % and 80.0% was recorded by male and females respectively (Fig. 36).

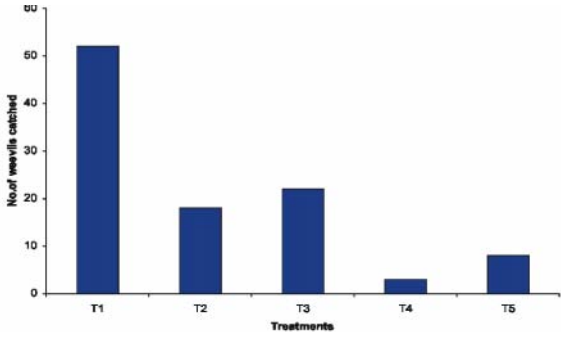
**Fig. 36 Wind tunnel bioassay of Sc.No. 1 against banana stem weevil, *Odoiporus longicollis*.**




$T_1$- Banana tissue (Cv. Nendran) 50 g; $T_2$- Sc.No.1 (1% solution –hexane as a solvent) 100 ul; $T_3$- Banana tissue (Cv. Nendran ) +Sc.No.1; $T_4$- Control (Hexane) 100 ul.

Based on the results obtained from olfactometry, a wind tunnel bioassay was conducted with selected / promising treatments (Fig. 37). Semiochemical No.1 + host plant volatile extract of susceptible cultivar was tested against both male and female weevils of *O. longicollis*. Maximum response of 88.0 % attraction was recorded in Semiochemical No.1 + host plant volatile extract of susceptible cultivar Nendran to male weevils, where as to female weevils, the response was 33.0 %. Host plant volatile extract of susceptible cv. Nendran recorded 66.0 % attraction to males and 67.0% to female weevils of *O. longicollis*. There was no differences in the percent of attraction between the sexes. Semiochemical No. 1 indicated a weevil response of 40.0 % to both the weevils.

**Fig. 37. Field evaluation of Sc.No. 1 against banana stem weevil, *Odoiporus longicollis*.**




T1- Sc.No. 1 + host plant extract; T2-Sc.No.1; T3- host plant extract; T4- Control; T5-stem trap.

Based on the results obtained from wind tunnel bioassay under laboratory conditions, a field evaluation trial was conducted using funnel trap in a weevil endemic areas of Theni and Dindigul districts of Tamil Nadu. Among the four treatments maximum weevil attraction was recorded. Semiochemical No.1 + host plant volatile extract of susceptible cultivar.

## Survey for collection, isolation and characterization of microbials

From 300 soil samples collected from banana plants grown in Srirangam taluk of Tiruchirapalli district, 44 isolates of White Muscardine fungus, *Beauveria bassiana* (Bals.), four isolates of White Halo fungus, *Lecanicillium lecanii* (Zimm.) and 7 isolates of Green Muscardine fungus, *Metarhizium anisopliae* (Metc.) were isolated and preserved for further use.

## Screening of microbial bio-control agents against corm weevil

The NRCB isolates of endophytic fungi, *Beauveria bassiana* was screened for it is efficacy against corm weevil. The tissue culture plant cv Grand Naine was injected with *Beauveria bassiana* as per the method developed by IITA (Akell et. al

2007) and after 30 days, the corm weevil was released into these plants and allowed to feed for 10 days and weevil mortality was recorded. The result of the study showed that among the 25 isolates, maximum weevil mortality of 32.0 % was recorded in the isolate NRCB en. Bb No. 5, 12, 13 and 17 and a minimum mortality of 12 % was recorded with the isolate NRCB en. Bb No.18. Weevil mortality of 90 & 100% was recorded in the standard check (NRCB EPF. Bb No.6) and pesticide (Chlorpyriphos) respectively. No weevil mortality was recorded in the control (tissue cultured plant without endophytic *B. bassiana*).

## 5.4.3. Investigation on fungal and bacterial diseases of banana and their management

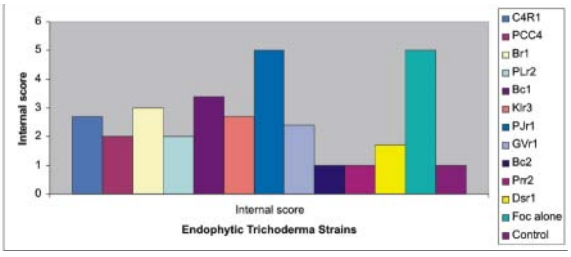
### Evaluation of rhizosphere Trichoderma spp. isolates against Fusarium wilt disease under pot culture condition

The evaluation of 6 isolates of rhizospheric *Trichoderma* spp. against *Foc* individually as well as in different combinations was carried out under pot culture condition in cvs. Grand Nain and NeyPoovan. The observation on growth parameters and disease severity of *Fusarium* wilt indicated that soil application of combination of *Trichoderma* spp. viz. $K_2T_5$ + *T. harzianum*, $K_2T_5$ + *T. pseudokoningii*, *Trichoderma* spp.- poovan + T. *harzianum*, *Trichoderma* spp. + *T. pseudokoningii* recorded the lowest disease score of 1.2 to 1.5 as compared to control (5.5).

### Pot culture evaluation of endophytic *Trichoderma* spp. isolates against Foc pathogen

Among 11 endophytic *Trichoderma* spp. evaluated against *Fusarium* wilt by root dip method in cv. Grand Nain, isolates Bc2 and Prr2 have given 100% protection against *Fusarium* wilt disease under pot culture condition. Besides, these isolates have increased the growth parameters such as height (169%), girth (205%), number of leaves (88%) and number of roots (230%) as compared to *Foc* alone inoculated plants (Fig.38).

**Fig.38 *In vivo* evaluation of endophytic *Trichoderma* spp. isolates against Fusarium wilt disease in cv. Grand Naine**




### Evaluation of endophytic and rhizospheric *Trichoderma* spp. isolates against Fusarium wilt disease under pot culture condition

Evaluation of combined application of 12 endophytic *Trichoderma* spp. isolates and two isolates of rhizospheric *Trichoderma* spp. viz. *T. koningii* and *T. harzianum* applied in different combinations @ 30g/ plant as rice chaffy grain formulation in cv. Grand Nain under pot culture condition indicated that application of endophytic *Trichoderma* strain BC2 + rhizospheric *T. koningii*, endophytic *Trichoderma* spp. strain Dsr1 + rhizospheric T. koningii and endophytic Trichoderma strain prr2 + rhizospheric *T. harzianum* isolate completely controlled *Fusarium* wilt disease and there was no expression of either external or internal symptoms of the disease even after 6 months after planting(Fig.39).

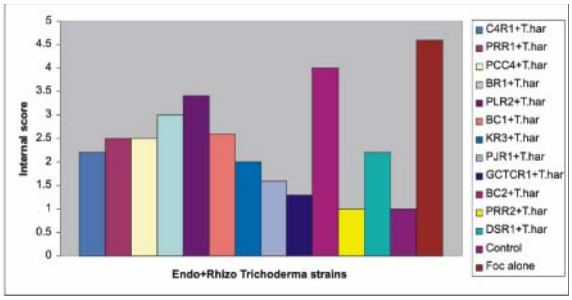



**Fig. 39 Effect of soil application of Endophytic *Trichoderma* spp. isolates + rhizospheric *T. harzianum* against Fusarium wilt disease in cv. Grand Naine**

### Pot culture evaluation of endophytic bacterial isolates against *Foc* pathogen

Among 6 endophytic bacterial isolates evaluated against Fusarium wilt disease in cv. strains Grand Nain. Root dipping of TC plants with Klr4 and Tvpr1 recorded the lowest disease score of 1.4 as against the disease score of 5.0 in the control. Besides, these isolates have increased the growth parameters such as height (61%), girth (84%), number of leaves (21%) and (150%) compared to *Foc* alone inoculated plants.

### Pot culture evaluation of combined application of rhizospheric and endophytic bacterial isolates against *Foc* pathogen

Combined application of 6 isolates of

endophytic bacteria and 4 isolates of rhizospheric bacteria as soil drench showed that application of endophytic bacteria *Pseudomonas putida* C4r4 + rhizospheric *Bacillus* spp. Jrb1, endophytic *Achromobacter* spp.Gcr1 + Rhizospheric *Bacillus cereus* strain Jrb5, endophytic *Rhizobium* spp. Lpr2 + rhizospheric *Bacillus* spp Jrb1, endophytic Bacillus spp Tvpr1 + rhizospheric Bacillus spp., endophytic *Bacillus* spp. Tvpr1 + rhizospheric *Pseudomonas putida* Jrb2 isolate completely controlled the *Fusarium* wilt disease (Score-1.0-healthy) (Fig. 40a).

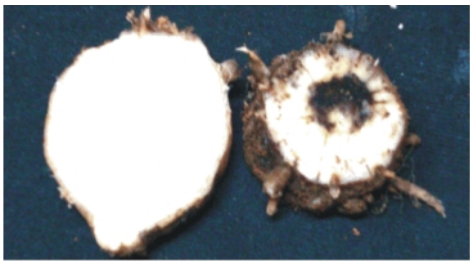


**Fig. 40a Complete inhibition of Fusarium wilt disease by the application of endophytic Trichoderma+ rhizospheric *Trichoderma* spp under pot culture condition at NRCB farm.**


**Fig. 40b Increase in number of roots due to the combined application of endophytic and rhizospheric bacteria**

## Compatibility of effective endophytic bacterial and actinomycetes isolates with certain effective fungicides

The compatibility of 6 effective endophytic bacterial antagonists and 5 endophytic actinomycetes with 3 different fungicides (Carbendazim, Difenaconazole and Propi conazole) effective against Fusarium wilt disease was assessed at five different concentrations (0.01 to 1%) by poison food technique in KB broth. The spectrophotometric reading of the bacterial suspension showed that there was no reduction in OD value due to the addition fungicides at all its concentration tested indicating that all these effective bacteria and Actinomycetes are compatible with all these three effective fungicides. This study gives scope that the antagonists can be applied along with fungicides for an efficient and effective management of the disease

## Pot culture evaluation of botanical extracts against Fusarium wilt disease

Among six effective botanicals evaluated against Fusarium wilt disease under pot culture condition, the botanicals such as *Alpinia* spp., *Hibiscus* spp. and Zimmu applied as dipping of plants for 1 1/2 hrs. + soil drench at @ 250 ml/ pot recorded 100% reduction of Fusarium wilt incidence compared to control (Fig. 41).

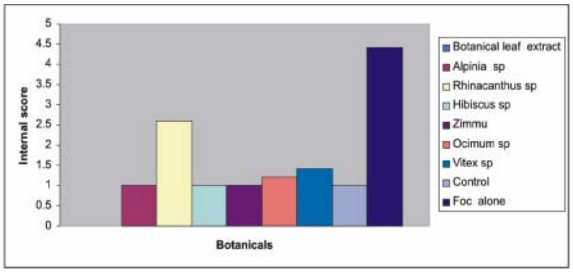



**Fig. 41 Pot culture evaluation of botanical leaf extracts against Fusarium wilt disease in cv. Grand Naine.**

## Pot culture evaluation of Zimmu extracts against *Fusarium* wilt disease

The pot culture evaluation of Zimmu at different concentrations from 5% to 100% applied as drenching and dipping against *Foc* in cv. Grand Naine indicated that either drenching of plants with zimmu extract at 50 or 100% or dipping the roots at 50 or 100% completely contained the disease. Besides, the treatment of Zimmu leaf extract has increased the growth parameters such as height (72%), girth (59%), number of leaves (39%) and roots (70%) compared to *Foc* alone inoculated plants.(Fig. 42).

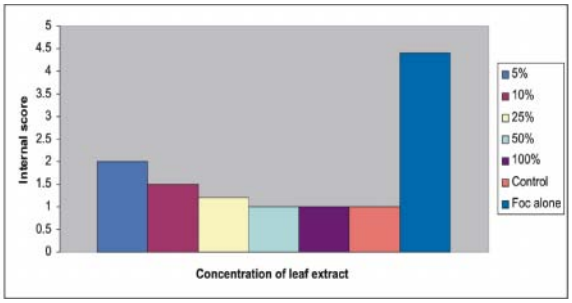



**Fig. 42 Effect of different concentrations of Zimmu leaf extract on Fusarium wilt disease in cv. Grand Naine.**

## Pot culture evaluation of non pathogenic Fusarium isolates against Fusarium wilt disease of banana

Out of 40 npFo isolates evaluated for their suppression ability of *Fusarium* wilt pathogen (0124) and also for their plant growth promoting abilities under pot culture condition in cv. Grand Nain indicated that the bio-priming of banana plants with endophytic npFo isolates resulted in significant increase in plant growth parameters such as height, girth, total no. of leaves, and also the total no of roots. Besides the npFo isolates significantly reduced the *Fusarium* wilt disease and complete controled the disease due to the application of npFo isolates PJr 1, CVrr 1 and Dsr 1.

## Pot culture evaluation of *Trichoderma* spp. isolates obtained from Kerala region against Fusarium wilt disease

Among 11 strains of *Trichoderma* spp. isolated from rhizosphere soil of banana collected from Kerala, three strains of *Trichoderma* spp. (KR4, 8 and 10) recorded complete suppression of *Fusarium* wilt disease under pot culture condition in cv. Grand Nain.

## Isolation of Principle compound from effective bio-control agents

Principle compound from the culture filtrate of effective *Trichoderma viride* isolate was isolated by $NH_4SO_4$ precipitation (20 to 100% conc.) method. The inhibitory effect of the $NH_4SO_4$ precipitate against *Foc* under *in vitro* condition by spore germination method was observed only at 90%conc. The further purification and identification of the compound are in progress.

# Sigatoka leaf spot disease

## Molecular characterization of leaf spot pathogens

Totally 96 isolates of *Mycosphaerella* spp. have been isolated from different cultivars of banana. The DNA isolated from these isolates was subjected to PCR amplification of rDNA-ITS region and got sequenced. The blast analysis indicated that the isolate of *Mycosphaerella* has 100% sequence homology with the *M.eumusae* indicating that the leaf spot pathogen is *M. eumusae*. The phylogenetic analysis using all these sequences indicated wide variation among the *M. eumusae* isolates.

## Genetic diversity analysis of *Mycosphaerella eumusae* pathogen by sequencing of rDNA - ITS region.

The genetic diversity analysis carried out for 75 isolates of *M. eumusae* by sequencing the rDNA - ITS region indicated that there is wide variation among the *M. eumusae* isolates obtained from different parts of the country. 11 different groups of *M. eumusae* isolates were observed and these were not either based on host source or genomic status of the host or the geographical region of the isolates (Fig. 43). From the RAPD analysis carried out for 75 isolates of *M. eumusae,* an unique band of 1000bp size specific to *M. eumusae* was observed. This will be useful to develop into SCAR marker (Fig. 44).

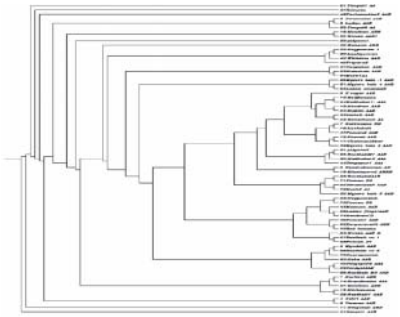


**Fig. 43 Phylogenetic analysis of *Mycosphaerella* spp. isolates by UPGMA analysis**

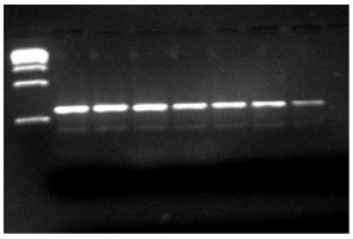


**Fig. 44 L - 500bp ladder, *1-6- Samples*, *7- +ve* control**

## Evaluation of endophytic and epiphytic bacterial isolates against eumusae leaf spot pathogen under field condition

The field evaluation of nine endophytic and two epiphytic bacterial isolates obtained from different parts of banana resistant to leaf spot disease indicated that application of these microbes generally reduced the *eumusae* leaf spot disease of banana significantly and the maximum reduction (43%) of leaf spot severity was observed by application of endophytic bacterial strain 6m2 compared to control plants. However, when

endophytic bacterial strain 5R and epiphytic bacterial strain 6E mixed individually with Banole oil 1%, 65% reduction of disease severity and 50% increase in number of green leaves were observed at vegetative phase compared to control.

### Standardization of diagnostic method for the leaf spot pathogen

The DNA isolated from the single spot of leaf spot disease obtained from Jalgoan of Maharastra state and also from Tamil Nadu was subjected to PCR amplification using *Mycosphaerella* species specific primer. The results indicated that the PCR amplification (amplican size of 650bp) was observed only in the primer specific to *M. eumusae* indicating that the leaf spot disease in these states is caused by *M. eumusae.*

### *In vitro* fungicide sensitivity test for M. eumusae pathogen

The *in vitro* fungicide sensitivity test for *M. eumusae* pathogen indicated that the Sigatoka leaf spot pathogen is sensitive to all the fungicides commercially available in the market viz. Propiconazole, Carbendazim, Mancozeb, Difenoconazole and Tridemorph at the conc. of 0.01 to 1%(Fig. 45).

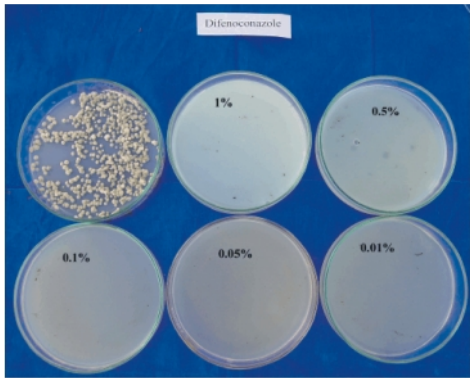



**Fig. 45** ***In vitro*** **evaluation of leaf spot pathogen for its sensitivity to different fungicides**

### Screening and evaluation of botanicals against eumusae leaf spot disease

Out of 33 botanical extracts evaluated *in vitro* against *M. eumusae,* three botanicals viz., *Cassia senna* (Ponaavarai), Zimmu (cross between *Allium cepa* X *Allium sativum*) and *Rhinacanthus nasutus* (Nagamalli) were very effective. The field evaluation of these effective botanical extracts at 5% conc. resulted in reduction of leaf spot disease from 46.4% to 50.7%. Besides, the leaf extract spraying, increased the number of green leaves up to 51% compared to control.

## 5.4.4. Studies on viral diseases and their management

### Survey for viral diseases in Tamil Nadu

Survey undertaken for the presence of viruses in Thottium taluk of Trichy district in cv. Mortaman revealed 1- 10% incidence of banana bract mosaic virus. In Thirukattupalli of Tanjore district, there was 3-8 % BBTV and 1 % BBrMV incidence in the tissue cultured plants.

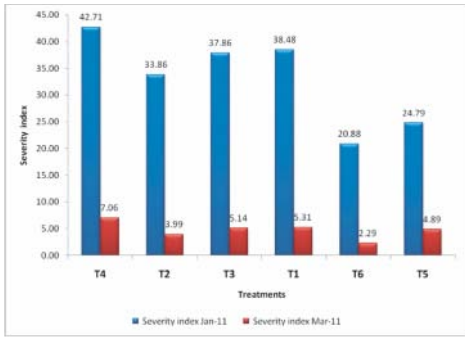
### Effect of increased dose of fertilizers on the yield of Poovan plants infected with BBrMV or BSV or both

The application of increased dose of fertilizer (150% of RDF), to the plants infected with BBrMV in the second ratoon crop of cv. Poovan has compensated the yield loss due to virus. There was no significant increase in bunch weight in plants having mixed infection (BBrMV and BSV) due to the application of higher dose of fertilizer.

### Expression of streak virus symptoms in cv. Poovan

Poovan plants expressing characteristic symptoms of BSV were planted during 2010. The severity index (SI) of BSV was ranging from 37.97 to 55.01 during January which reduced significantly during March 2011(2.29-7.06) (Fig.). The severity index was higher in treatments with organic than inorganic fertilization. It can be concluded that the expression of symptoms was influenced by temperature as well as level of organic and inorganic fertilizer treatments imposed to plants (Fig. 46).

**Fig. 46 BSV expression in different fertilizers treatments in cv. Poovan**




T1 - 9kg FYM+2kg VC; T2 - 12kg FYM+1.5kg VC; T3- 15kg FYM+1.25kg VC; T4 - 20kg FYM+1kg VC; T5 - 150 g Urea+ 250g SSP+150g MOP; T6 - 100 g Urea+ 200g SSP+100g MOP

## Molecular Characterization of banana viruses

Complete coat protein gene of eight different BBrMV isolates collected from Tamil Nadu, Andra Pradesh and Kerala was amplified using either degenerate primers specific to genus potyvirus or BBrMV coat protein gene specific primers. The sequence analysis revealed that a maximum of 19% variation was observed in a Thirukattupalli isolate as compared to already published sequences which are available in the NCBI.

Banana Mild Mosaic Virus (BaMMV) specific primers have amplified an expected fragment from Karpuravalli which exhibited mild mosaic symptom. This is the first report of BaMMV in India.

In Banana streak virus infected Poovan banana, a putative full length BSOLV sequence with ~7kb size was amplified and cloned into pGEM-T vector. The clone was sequenced and confirmed that 1.5 kb of RT/RNAse region was missing. Restriction analysis performed using BamH I, Hind III, DraI, Pst I and EcoR I enzymes showed that 1.5kb was not present in the full length nucleotide sequence. Putative full length BSOLV sequence was amplified using DNA from BSV infected Rasthali banana. The PCR product of ~5.5kb size was amplified and restriction analysis was done using PstI.

## Expression of recombinant coat proteins of BBTV, BBrMV and BSMysV in *E.coli*

Coat Protein gene of BBTV was amplified and cloned into pET vector and~20KDa protein was expressed by IPTG induction. In case of BBrMV, polyclonal antiserum was produced using partially purified recombinant protein (6XHis tag), but the antiserum was cross reacting with healthy plant proteins leading to false positives in ELISA. Therefore, a full length of BBrMV-CP has now been cloned into pET expression vector. The IPTG induction has expressed protein of 34kDa size and this has been obtained in insoluble form as inclusion body. This expressed protein will be used for raising antiserum.

BSMysV- ORF II was amplified using forward and reverse primers containing NdeI and XhoI respectively. NdeI/ XhoI restricted PCR product was cloned into restricted pCOLD-I vector and confirmed by sequencing. Induction was done using IPTG and ~18kDa protein was expressed in insoluble form.

## Supply of virus indexed hill banana mother plants

Healthy and virus free suckers of Grand Naine and Virupakshi varieties are being maintained in the field for supplying to the farmers. So far, 540 number of BBTV free suckers of Hill banana were supplied to the farmers during 2010-11.

## Screening Musa germplasm against viruses

Fifty five banana germplasm accessions received from NBPGR, New Delhi were screened against four different banana viruses and of which 39 accessions were found positive for BBrMV and 17 for BSMysV. Some of the accessions were positive for both BBrMV and BSMysV.

Similarly, screening of 60 germplasm accessions conserved in the field gene bank of NRCB for all the four banana viruses indicated that 31 out of 60 were found positive for BBrMV and only 11 were negative for BSMysV. Besides, 26 germplasm samples received from AICRP (TF) centers viz., Arabhavi, Karnataka and TNAU, Tamil Nadu, screened against banana viruses showed that 15 were found positive for BBrMV.

## Diagnostic techniques for banana viruses

To improve the sensitivity of detection of BBrMV, a set of primers has been designed and validated by comparing with already published primers. The results showed that the newly designed primer was found superior in detection of BBrMV. Four new sets of primers were designed to improve the sensitivity of multiplex RT-PCR, for testing each viruses.

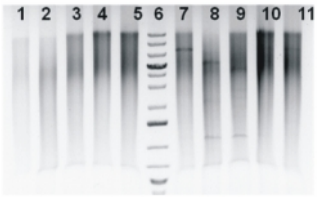
Primers and probes (TaqMan probe) were designed for BBTV and BSMysV in collaboration with DSMZ, Germany. Using these primers, real time PCR (RT-PCR) procedure has been standardized for detection of BBTV. By using SYBR Green, the BBTV coat protein gene was amplified from the bunchy top symptomatic samples.

Rolling circle amplification (RCA) approach which uses bacteriophage Phi29 DNA polymerase has been applied for detecting the Banana Streak Mysore Virus (BSMysV) and BBTV. The amplified products were digested using 2-3 units of a restriction endonuclease according to the manufacturer's instructions and then electro phoresed through agarose gels. By this approach,

episomal virus of BSMysV in Poovan and BBTV in Hill banana were detected (Fig.47) .

## Association of BBrMV and BSV in other plant species

**Fig. 47 Detection of BSMysV using RCA-RFLP approach**




Lane 1-5-Poovan Healthy; Lane-6 1kb ladder; Lane 7-11 Poovan Symptomatic; Lane 1, 7 –BamHI; Lane 2, 8-HindIII;Lane 3, 9 -NcoI; Lane 4, 10 -SalI;Lane 5, 11-XhoI

Symptoms similar to BBrMV were observed in cardamom collected from Kerala. Partial genome was amplified using potyvirus degenerate primers, cloned and sequenced. Sequence analysis revealed that the virus was Indian cardamom mosaic virus. Partial fragment of BBrMV covering part of the CP gene and 3'UTR was amplified from another sample of cardamom collected from Kerala using bract 1 and bract 2 primers. The amplified fragment was cloned and sequenced. The results showed that 92% similarity with the published BBrMV sequences indicating variability among BBrMV isolate.

Ornamental ginger sample exhibiting symptoms similar to BBrMV in banana was collected from Delhi. Partial genome was amplified using potyvirus degenerate primers cloned and sequenced. Sequence analysis revealed that the virus belongs to bean yellow mosaic virus of the genus potyvirus.

Banana streak virus species (BSMysV and BSGFV) was also amplified, cloned and sequenced from badnavirus infected citrus leaf sample. The results indicated possible association of BSV in citrus.

## Ring test for the detection of banana viruses

Ring test is generally used for validating plant viruses indexing protocol. Bioversity, France and QDPI, Australia jointly undertook this ring test for banana viruses. This test was performed at three different labs including NRCB. Blind samples were supplied by the QDPI and the total DNA and RNA were isolated. The samples were assayed by PCR methods as given in the *Musa* Indexing Manual developed by Dr J.E.Thomas, QDPI. Except for BBTV and CMV, all the other primers were used as given in the *Musa* Indexing Manual. In case of BanMMV, degenerate primer designed by J.E.Thomas, QDPI was used for amplification. The results showed that this ring test detected viruses in the blind samples except CMV. However, there were few false negatives and positives in the test from all the three labs and this necessitates careful handling of PCR.

## Development of transgenic plants for CMV resistance

*In planta* transformation, a new approach was used for development of transgenic Grand Nain. A total of 69 plants were co-cultivated with CMV cp gene, but none of them were shown PCR positive.

# Host virus interaction in Banana: Molecular mechanism of resistance and susceptibility, latency, integration and episomal expression of EPRV's"

## Permanent field trial to study the natural expression of BSV in Poovan

Non -symptomatic Poovan plants planted during the year 2005-06 have been continued this year (2010-11) also as fifth ratoon crop. During this year, the expression of streak symptoms typical to BSV's was observed in 27 plants. So far, 79 plants out of 700 plants have expressed the symptoms of streak disease. Eighteen plants which expressed symptoms in the previous year (2009-10) did not express symptoms this year. The yield reduced drastically in the 4$^{th}$ ratoon crop compared to previous crops. This showed gradual decline of yield due to BSV.

## Standardization of FISH studies

As a prerequisite for Fluorescent *In-Situ* Hybridization (FISH) which locates endogeneous pararetroviral sequences (EPRV's) of BSV in banana and plantain, a technique was standardized for staining and visualizing different stages of chromosomes in Poovan and other 'B' genome harboring clones according to the suggestion made by Dr. Heslop Harrison, UK. Fluorescent staining with DAPI for observing the nuclei has also been standardized.

## Characterization of miRNA in BSMysV infected plants

Virus responsive microRNA such as miR156, 159, 160, 164, 166 and 169 were amplified using

primers designed based on the computational prediction. Except miR160 and 164, others were amplified and cloned into pTZ57R/T vector and confirmed by restriction analysis. Two clones from each miRNA were sequenced. miR-159 was confirmed in sequencing and secondary structure of precursor miRNA was predicted from sequence obtained. Target of miR-159 was also predicted such that it is specific for targeting MYB transcription factor.

### Integration pattern of BSOLV in chromosome of banana cultivars

Three sets of primers were designed to identify BSOLV integration pattern in different 'A' and 'B' genomes cultivars. A similar pattern of integration found in Obino L' Ewai was observed in cv. Poovan (AAB), Nattu Poovan (AB) and Karpuravalli (AAB). But no such expected amplification was obtained in Rasthali (AAB) and Cavendish group (AAA). This result showed that Rasthali being AAB, it might contain a different integration pattern as that of Poovan. When a full length BSOLV sequence of size 6950bp was cloned and sequenced, 492 bp (6543-7035) was missing in the region of RT/RNase. Primer targeting the missing region was designed. Amplification of an expected size was observed in cv. *Musa balbisiana* and Rasthali but not in cv. Poovan.

### Study on the latency of BBTV using real time PCR analysis for viral transcripts

BBTV was transferred through viruliferous aphids (*Pentalonia nigronervosa*) to the virus free tissue culture plants of cultivar Grand Nain. Out of 12 plants, seven were positive in PCR, but only four plants exhibited symptoms after 32-58 days and three have not exhibited the symptoms for more than two months. Positive plants are being observed for the symptoms expression.

Primers and probe have been designed for rep gene of BBTV to assess the quantity of its transcripts in latent and severely infected plants using real time PCR. Twenty ex-agar plants of BBTV positive Grand Nain received from a TC firm were hardened for two months and tested for BBTV by PCR. All plants confirmed positive without exhibiting any symptoms. 300 Plants which were positive for BBTV in our indexing service have been mass multiplied through tissue culture by M/s SPIC, Coimbatore.

### Rolling Circle Amplification (RCA) approach for distinguishing BSV species in different cultivars

Rolling circle amplification was performed using DNA samples of BSV infected at healthy Rasthali and Poovan cultivars. The amplification was observed only from the DNA isolated from infected samples but not absent in healthy Poovan DNA samples. Then restriction analysis was done using single cutter enzymes which differentiated BSMysV and BSOLV. Sal and Xho are specific to BSMysV and absent in BSOLV. Likewise, Nde is specific to BSOLV and absent in BSMysV. Also, two and three cutter enzymes such as Eco, BamH and Pst were used to differentiate these two BSV species. This result indicated that streak symptomatic banana cv. Rasthali had BSMysV. Based on RCA and PCR amplification with abutting primers showed that streak symptom exhibiting cv. Poovan had both BSMysV and BSOLV species. However, further confirmation through sequencing is needed.

Abutting primers for BSMysV was designed and amplified in infected cvs. Poovan and Rasthali. Full length sequence of BSMysV was amplified from streak symptomatic Poovan and Rasthali bananas. Two bands were obtained at a size of 7650bp and ~5kb from both the cultivars. Restriction analysis carried out for 7650bp fragment using Bam H, Hind , Nco, Pst and EcoR showed that the restriction pattern is similar to previously reported BSMysV sequences.

### Development of RNAi based multiple virus gene construct

Multiple virus gene construct was sequenced and the sequence analysis revealed that the insert size was 1.6 kb but the virus gene sequences were in the same orientation. Therefore, an alternate approach is being attempted to change the orientation of the insert.

## SSH analysis

### Isolation of RNA from BSMysV infected and healthy leaves of Poovan banana

For SSH analysis, RNA was isolated from leaves of BSMysV infected and healthy Poovan at its different stages of plant growth. The quality and integrity of RNA was visualized on a non-denaturing 1% agarose gel electrophoresis. The results showed that the total RNA exhibited two

bright bands corresponding to ribosomal 28S and 18S RNA with an intensity ratio of ~1.5-2.5:1 which is highly suitable for SSH work.

### Promoter studies

Co-cultivation of leaf disc and infiltration methods of transient gus assay for BSMysV derived promoters in *N. tobaccum* xanthi were done using GUS as reporter gene. This transient gus assay revealed on par expression of BSMysV and CaMV promoter at 24 hrs, 48hrs and 110 hrs. *In silico* analysis of intergenic region 1, 3 and 6 component of BBTV revealed the presence of most of the motifs in the widely used 35S CaMV promoter. BBTV-IG3 promoter constructs have been developed to assess its efficiency. Agrobacterium mediated transformation in tobacco (*N. tobaccum* xanthi) with BSMysV and CaMV derived promoter constructs having GUS gene was carried out. Tobacco leaf disks were co-cultivated with both the constructs. Shoots have been developed and they are maintained in rooting medium. The concentration of Kanamycin required for the selection of transformed callus was also standardized.

## 5.5. EXTERNALLY FUNDED PROJECTS

### 5.5.1. Accreditation Test Laboratory for Certification of Tissue culture raised plant material under NCS-TCP

Grand Nain, Robusta and Sabri samples have been tested for their genetic fidelity using SSR and ISSR markers and test reports have been issued for 12 commercial tissue culture units.

### 5.5.2. Regeneration and safety duplication of priority *Musa* collections

Biometric data of 198 priority Musa accessions identified under the project has been completed with four replications.

Morphotaxonomic characterization for 121 traits of the plant crop has been completed for all 198 accessions.

Photographic descriptor (minimum descriptor for 15 qualitative traits) is completed for 88 accessions.

142 accessions from the priority 200 accessions were initiated in-vitro for conservation at NRCB.

Of the 60 accessions to be deposited with ITC, DARE clearance has been obtained for 50 accessions which are common under Cryoconservation project operative at NBPGR.

All 60 accessions to be deposited with ITC, Belgium, first batch of 54 accessions have been regenerated in-vitro and deposited with NBPGR for onward export.

Efforts are being made to get DARE clearance for the additional 10 accessions committed by NRCB for transfer to ITC, Belgium through NBPGR, New Delhi.

Virus indexing is completed for 60 accessions for four major banana viruses (BSV, BBTV, BBMV and CMV).

### 5.5.3. Screening of banana germplasm for drought for the benefit of resource poor farmers

To identify drought resistant/tolerant plants, several genotypes viz., Paglapahad wild, Attikol , Karpuravalli, Peyan, Kothia , Vennuttu mannan , Saba, Monthan, Nendran, Poovan, Chinali, Rasthali, Jwari bale, Ney Poovan, Robusta, Red banana, Pisang Jari Buaya, Calcutta 4 were planted in the field. Six months after planting, soil moisture stress was imposed by withholding irrigation in the treatment and control plots. In this case of normal irrigation was given at 10 day's interval, when the available soil moisture was between 27-31%. In the treatment plot, the soil moisture and soil matric potential were recorded. The drought stress was imposed for 4 weeks, based on our previous experimental data and later the stress was relieved with normal irrigation. At the end of drought stress treatment, the soil matrix potential was recorded as - 0.6 MPa.

The average phyllochron of drought stressed plants recorded was 11 days / leaf compared to 8.5 days in irrigated control. The senescence of drought-imposed plants recorded was 1.04 leaves / week compared to 0.56 leaves / week in irrigated control.

At the end of stress period, Paglapahad wild, Vennuttu mannan, Jwaribale and Poovan recorded higher plant water potential ca. -0.71 MPa compared to average of all other stressed genotypes (- 0.592 MPa). Similarly, they were also maintained higher RWC (>70 %) compared to average of all other stressed genotypes (65%). Based on these traits, it appears that, these genotypes are tolerant to soil moisture stress during vegetative stage. The yield for irrigated and

drought imposed treatments are yet to be assessed and the experiment is in progress.

Peroxidase enzyme profile was used as one of the tools for screening across drought tolerance and susceptible *Musa* cultivars. The results were contradictory, suggesting that peroxidase profile cannot be used for screening purpose. PWP was determined for three different cultivars across different genotypes (Grand Nain, Udhayam, Monthan) using uniform tissue culture raised plants and it was obtained that the PWP was commonly ranged from 18-22 days.

## 5.5.4. Development of DUS Guidelines for Banana

Identification of testaccessions representation of all genomes and ploidies

Field multiplication of selected reference accessions at NRCB, Trichy

Planting of 30 reference accessions in two locations namely, NRCB, Trichy and HRC, Tripura

Multiplication and supply of duplicate sets of 30 test accessions to Dapoli and Bihar centers of PPV & FRA

Conducted one training programme and one awareness campaign

Orientation and discussion programme on Framing Crop Specific DUS Guidelines for banana from officers from the Co-op center at Agartala, Tripura from 21-23 September, 2010.

Training cum Awareness programe on "PPV and FR for farming community" on 10 Feb.2011 which was attended by more than 100 farmers.

## 5.5.5. Induced mutation - A crop improvement strategy for developing Dwarf and Sigatoka leaf spot resistant banana cv. Grand Nain

### Irradiation and Challenging the plants with the pathogen

Embryogenic Cell Suspension (ECS) produced from test cultivar Grand Naine was irradiated at various doses ranging from 10 Gy to 50 Gy at SBI and BARC. It was found that somatic embryos were produced when ECS irradiated below 30 Gy. Whereas, proliferating meristems irradiated between 25 to 35 Gy regenerated into plants. The irradiated plantlets derived shoot tips and ECS of cv. Grand Nain were used for screening for positive mutants (resistant to Sigatoka leaf spot) using the toxin juglone. Irradiated plantlets were also challenged with *Mycosphaerella eumusae*. After 50 days of inoculation, out of 107 plants, 22 have shown partial tolerance (10% spots) over control. These plants have been shifted to field for screening under open conditions.

### Development of markers for dwarfness

A total 50 samples each of normal and dwarf types were collected and subjected to RAPD analysis for developing SCAR markers using 32 random oligonucleotide primers from Operon Technologies Inc. (Alamada, CA). Out of 32, 20 primers resulted in consistent and informative profiles. Among these 20, OPA-05 (5'-AGGGGTCTTG-3') amplified a band of 900bp in single plant which corresponded to dwarfism. Hence, the above amplicon identified as a discrete band could be developed into a diagnostic marker.

## 5.5.6. Fusarium wilt

### Genetic diversity of *Foc* isolates by RFLP analysis of trans -elongation factor -1

Genetic diversity analysis was carried out for 91 isolates of *Foc* which includes 66 representative *Foc* isolates collected from different parts of India, 15 isolates of VCG obtained from Australia (for comparison) and 10 isolates of non- pathogenic *Fusarium oxysporum* (npFo) were carried out by RFLP analysis of elongation factor region using 4 different restriction enzymes *viz*., Hha I, Msp I, Rsa I and Taq I. The banding pattern obtained for all the restriction enzymes indicated the presence of 15 different groups. Among these, the group 1 has 80% of the Indian *Foc* isolates and grouped under race-1 VCGs obtained from Australia. Interestingly, this RFLP analysis has clearly distinguished the VCGs of race-1 and race-2 from the VCGs of race-4 isolates. Besides, this RFLP analysis has grouped all the npFo isolates in the group1 meaning that this analysis grouped all the *Foc* isolates including *Foc* in one group but failed to distinguish the pathogenic Fo from the npFo.

### Genetic diversity analysis of Indian *Foc* isolates by RFLP analysis of EF a 1 region

### Validation of *Foc* specific molecular marker under field condition

### Diagnosis of *Foc* the plant

DNA was isolated from root, corm and pseudostem of both *Foc* infected and non infected plants and subjected to PCR amplification using *Foc* specific SCAR marker which has already been tested successfully under *in - vitro* condition. The result indicated that the SCAR marker detected the pathogen present in corm and pseudostem of infected plants (Fig. 48). The standardization of detection of *Foc* pathogen in the roots is in progress.

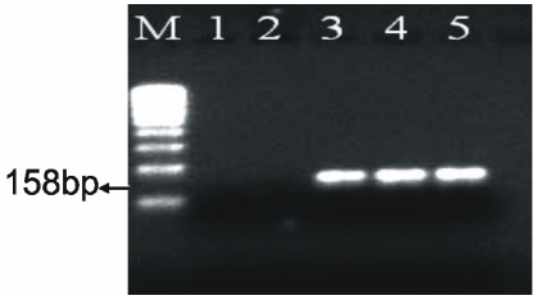



**Fig.48 M – Marker (100 bp) 1. Control (without infection) 2. Root 3. Corm 4. Pseudostem 5. *Foc* culture**

### Detection of *Foc* pathogen in the soil

The easiest method of DNA extraction from just 2 g of soil without PCR inhibitors has been standardized. The DNA extracted from different soils of infested or non- infested have been subjected for PCR amplification using *Foc* specific SCAR marker. The result indicated that the SCAR marker has generated expected amplicon only from the *Foc* infested soil indicating that the SCAR marker can be used to detect the presence of pathogenic *Foc* present in the soil.

### Genetic diversity of effective *Trichoderma* spp.

Genetic diversity analysis carried out for 27 endophytic and 16 rhizhospheric *Trichoderma* spp. by rDNA-ITS -RFLP analysis using 6 restriction enzymes viz. EcoRI, HhaI, HinfI, TaqI, MspI, grouped all the 43 isolates of *Trichoderma* spp. in to two major clusters viz. A & B. The cluster A contains 20 isolates of *Trichoderma*, of which, 14 are rhizospheric and 6 are endophytic *Trichoderma* spp. isolates. The cluster B contains 23 isolates of *Trichoderma* spp. of which 21 are endophytic and two are rhizospheric. From the phylogenetic analysis, it was concluded that the rDNA-ITS -RFLP analysis separated all the *Trichoderma* isolates in to two major groups based on their habitat ie as endophytic and rhizospheric. However, this phylogenetic analysis could not differentiate the *Foc* effective *Trichoderma* spp. isolates from the *Foc* ineffective *Trichoderma* spp. isolates.

## 5.5.7. AMASS-Project

### Pot culture evaluation of VAM isolates for their efficiency to infect the roots of Banana and for root characters promotion

The soil application of four effective VAM isolates was evaluated for their efficiency to infect the roots of banana and for root character promotion under pot culture condition in cv. Grand Naine. The result of the study indicated that all the isolates had 60 to 80 % infection of banana roots and significantly increased the no. of roots which was ranged from 91% 191% and also the root biomass (154 to 358%). The VAM inoculation also had no infection of nematodes except in one isolate which was taken from Tripura.

### Pot culture evaluation on the effect of MHB isolates on the root characters promotion

The evaluation of soil application of 11 bacterial isolates of MHB isolated from the spores of VAM individually under pot culture condition in cv. Grand Naine indicated that all the MHB isolates generally increased the number of roots as well as root biomass significantly which was ranged from 49 to 163% and 7.0% to 243% respectively. Among the MHB isolates, the *Pseudomonas* spp. isolated from VAM strain Kp2 and *Streptomyces* spp. isolated from VAM - Tripura excelled the other isolates in increasing the root characters. With regard to nematode infection, the isolate *Enterobacter* from LP-1, *Rhizobium* sp. from Kp2, Azotobacters from Kp2, Enterobactor from Kp2, *Pseudomonas* sp. from Kp2 and *Klebsiella* sp. from K4 had no nematode infection and other isolates had nematode infection of up to 0.7%.

### Effect of soil application of combination of VAM +MHB on the percent root infection by VAM and also on the promotion of root characters

Pot culture evaluation was carried out to assess the role of MHB in helping the VAM isolates in increasing the root infection and also promoting the root characters under pot culture condition in cv. Grand Naine. The result of the study indicated that among the various combinations tried, the

VAM+ Enterobacter, VAM+ Rhizobium, VAM+ Azotobacter, VAM + *Bacillus* spp. VAM + Enterobacter -T recorded 100% infection by VAM and increased the root numbers ( up to 417%) and root biomass (up to 806%) significantly when compared to control.

### Pot culture evaluation VAM for their efficiency to infect the roots of Banana and for root character promotion

The soil application of four effective VAM isolates was evaluated for their efficiency in promoting the growth parameters under pot culture condition in cv. Grand Naine. The result indicated that all the isolates had significantly increased the plant growth parameters such as height (21.32 to 33.29%), girth (26 to 63%), total no. of leaves (6%) and leaf area (up to 53%).

### Pot culture evaluation on the effect of MHB isolates on plant growth promotion

The evaluation of soil application of 11 bacterial isolates of MHB isolated from the spores of VAM individually under pot culture evaluation in cv. Grand Naine on plant growth promotion indicated that all the MHB isolates generally increased the plant growth parameters such as height (up to 59%), girth (47%), total no. of leaves (18%) and leaf area (up to48%) (Fig. 49).


**Fig. 49 Increase in growth and root parameters in the VAM strain KPV treated banana plants**

### Effect of VAM application on the available Phosphorus in cv. Grand Naine

Totally 25 isolates of VAM were evaluated for their efficiency in solubilishing the unavailable phosphorus under pot culture condition in cv. Grand Nain. After one month of application of VAM, the available phosphorus was estimated. Application of VAM generally increased the available phosphorus (up to 1700%) significantly when compared to control. Among the VAM isolates, the VAM isolated from Pisang jaribuya recoded maximum increase of available phosphorus compared to other isolates.

## 5.5.8. Development of transgenic Hill banana resistant to BBTV (replicase mediated)

The final report of the project along with consolidated financial statement has been prepared and submitted to DBT and to the coordinator of the net work project.

## 5.5.9. Network Project on Transgenic in Crops -Transgenic Component (NTPC-PC 3042)

### Developing transgenic banana resistant to BSV and BBTV (cp mediated)

Totally 80 *in planta* transformed plants with cp gene construct of BBTV, were analyzed for the presence of cp gene by PCR. Out of 85, plants 35 were positive in PCR. DNA from these plants were isolated and blotted onto NCM for southern analysis. For transgenic works, a total of 208 male buds of hill banana free from BBTV were used to initiate the cell suspensions.

## 5.5.10. DBT-Accredited Test Laboratory under NCS-TCP

### Testing for banana viruses for certified banana tissue culture laboratories in India

Tissue culture samples were tested for banana viruses under DBT -ATL scheme. Totally 11,349 samples had been tested for the presence of virus, out of which, 4117 samples were analyzed for BBTV, 1985 for BSMysV, 2026 for BBrMV and 3221 samples for CMV. The result of the analysis indicated that 460 samples shown positive for BBTV, 193 for BBrMV, 42 for BSMysV and 38 samples shown positive for CMV.

# 6 TECHNOLOGY ASSESSED AND TRANSFERRED

## Radio Talks

| Name of the Scientist | Topic | Date of Broadcast/ Radio |
|---|---|---|
| Saraswathi, M.S | Selection and maintenance of tissue culture | 09.04.2010 AIR, Trichy |
| Mayil Vaganan, M | Improved postharvest technologies in banana (in Tamil) | 15.05. 2010 AIR, Trichy |
| Uma, S | Economical measures in banana production (in Tamil) | 08.09.2010 AIR, Trichy |
| Selvarajan, R | Certification for banana - a live programme (in Tamil) | 8.12.2010 AIR, Trichy |

## Television Talks

| Name of the Scientist | Topic | Date of Telecast / TV |
|---|---|---|
| Jeyabaskaran, K.J | Micronutrient deficiency in banana (in Tamil) | 10-09-2010 *Makkal TV*, Chennai |
| | Soil suitability for banana and micronutrient management in banana (in Tamil) | 06-12-2010 *Doordharshan (Podhigai), TV* , Chennai |
| Mustaffa, M.M | About NRCB activities (in Tamil) | 10.11.2010 *Doordharshan(Podhigai) TV*, Chennai |
| | About NRCB (in Tamil) | 5.12.2010 *Makkal TV*, Chennai |
| | Handling and processing of banana (in Tamil) | 6.12.2010 *Makkal TV*, Chennai |
| Padmanaban, B. | Pest control of banana (in Tamil) | 7.12. 2010. *Makkal TV*, Chennai |
| Saraswathi, M.S | Selection and maintenance of tissue culture plants(in Tamil) | 07.04.2010 *Makkal TV*, Chennai |
| | Selection and maintenance of tissue culture plants(in Tamil) | 17.09.2010 *Doordharshan(Podhigai) TV*, Chennai |
| Selvarajan, R. | Viral diseases of banana and their management (in Tamil) | 30.11.2010 *Doordharshan(Podhigai) TV* , Chennai |
| Shiva, K.N. | Extraction of banana fiber and production of handicrafts (in Tamil). | 18.11.2010 *Doordharshan(Podhigai) TV* , Chennai |
| | Production of value added products from banana (in Tamil) | 25.11.2010 *Doordharshan(Podhigai) TV*, Chennai |
| Thangavelu, R. | Fungal & bacterial diseases of banana and their management (in Tamil) | 22.11.2010 *Doordharshan(Podhigai) TV* , Chennai |
| | Mass production of biocontrole agents for the control of Fusarium willt diseases (in Tamil) | 16.12.2010 *Makkal TV*, Chennai |

| | | |
|---|---|---|
| Uma, S. | Success story of Udhayam banana (in Tamil). | 05.04.2010<br>*Makkal TV*, Chennai. |
| | Production of banana suckers by simple methods (in Tamil) | 07.04.2010<br>*Makkal TV*, Chennai |
| | Production of banana suckers by simple methods (in Tamil) | 16.09.2010<br>*Makkal TV*, Chennai |

## Exhibitions conducted/ participated

| Name of the Events | Organized by/ venue | Date(s) |
|---|---|---|
| Banana Festival | Horticulture Association Ernakulam Dist, Cochin, Kerala | 28.4 - 2.5. 2010 |
| Swadesh Prem Jogriti Sangsothi-2010 | IIHR, Bangalore, Karnataka | 29 - 30.5. 2010 |
| Extension Reforms | TNAU & ATMA, Trichy, TN | 7 - 8. 7. 2010 |
| Kissan Mela | NRCB, Farm ,Trichy | 21.8. 2010 |
| Agri Expo - 2010 | Dinakaran, TNAU & State Agrir. Dept. Trichy, TN | 24 - 26 .9. 2010 |
| Science Exhibition -2010 | NRCB & State Govt. School, Ettarai, Trichy, TN | 4.10. 2010 |
| International Conference on Coconut Biodiversity for Prosperity | CPCRI, Kasaragod, Kerala | 25 - 28.10.2010 |
| Global Conference on Banana 2010 Managing Emerging Challenges of Biotic and Abiotic Stresses in Banana and Plantain | AIPUB and NRCB, Trichy | 10 -13.12. 2010 |
| 3rd Agri Expo- 2011 | Dinamalar, TNAU & State Agri. Dept. TN, Trichy | 28 -31. 1. 2011 |
| NSCFT - 2011 (National Seminar on " Climate Changes and Food Security: Challenges and Opportunity for Tuber crops") | CTCRI, Sreekariyam, Kerala | 20 - 22.1. 2011 |
| Udyan Mela - 2011 (NCPDPM-2011) | CPRI, Modipuram, UP | 5 - 6.3. 2011 |

Prof. K.V. Thomas, H'ble minister of state for Agriculture, GOI and Dr. S. Ayyapan, DG, ICAR, New Delhi visit to NRCB exhibition stall at CPCRI, Kasaragod, Kerala during International Conference on Coconut Biodiversity for Prosperity (28.10.10)


Visitors at NRCB stall during the exhibition organised by Dinakaran and TNAU, Trichy on 24.9.10.

# 7 EDUCATION AND TRAINING

| Student Name | Degree | Project Title | Guide Name |
|---|---|---|---|
| N. Nagajothi | M. Sc. | Studies on salt stress responsive proteins in salt-sensitive banana cultivar, Grand Naine | M.Mayil Vaganan |
| Diana | M.Phil | Development of cleaved amplified polymorphic markers from resistance gene analogue for identification of Fusarium resistance gene | S. Backiyarani |
| P. Shobana | B.Tech | Development of RGA-CAP marker and EST-SSR markers in Musa | |
| R.Yogachandru | M.Sc | Studies on the use of low cost alternatives in tissue culture of banana variety Udhayam | M. S. Saraswathi |
| D. Rahamathunnisa | M.Sc | Screening of Rasthali mutants using ISSR markers | |
| T. Anand Sastra | M.Sc | Genetic relationship analysis among parents and progenies - extent of variation between leaf and seed DNA | S. Uma |
| S.M.Bhuvaneswari | M.Sc | Identification of resistant genes in Musa cv. Manoranjitham (AAA) | |
| S.Ranjini | M.Sc | Gene expression studies in Musa cv. Manoranjitham (AAA) using Real Time PCR | |
| N. Kruthiga Ponnaiah | M.Sc | Standardization of in-vitro multiplication and regeneration protocol for Musa boman, a recalcitrant exotic banana variety. | |
| C. Kalaivani | M.Sc | Comparative analysis of promoter from BBTVs and CaMV | C. Anuradha |

## Trainings

Training on 'Micro and Macropropagation in banana' to the officials and farmers of Tamil Nadu, Kerala, Uttar Pradesh, Gujarat, Assam and Bodoland.

Demonstrated macro - propagation technology developed at NRCB to the farmers of Kerala under SHM and Namakkal under ATMA and imparted the knowledge on the selection of ideal tissue culture planting material and their initial care and maintenance.

An 'Awareness cum Training programme' on Protection of Plant Varieties and Farmers Rights Act organized at NRCB, Trichy on 10.02.2011.

Organized 'Project Orientation and Discussion' for the State Govt. officials of Horticultural Research Complex, Nagicherra, Agartala of Tripura under DUS project from 21 to 24, September 2010 at NRCB, Trichy.

Dr. M.M. Mustaffa, Director NRCB, delivering a lecture on technology developed at NRCB to the farmers of Kerala

# 8 AWARDS AND RECOGNITIONS

## Awards

Lakshmi, S, Uma. S and Akbar, A. received 'Best Oral presentation Award' for the research paper entitled "*In-vitro* studies on the factors affecting plant germination in zygotic embryos of *Musa* species" in the DBT sponsored National Symposium on *In silico* and *in-vitro* studies in biology, held on 11-13 October, 2010 at Holy Cross College, Bharathidasan University, Trichy, Tamil Nadu.

Maiyl Vaganan, M. received "Best Poster Award' for the research paper entitled 'Quality evaluation of banana varieties for specific target groups' authored by Shiva, K. N., Mayil Vaganan, M. and Mustaffa, M. M. in the 4th Interactive Workshop on Biotechnological Applications for Sustainable Development held on 12 & 13 March, 2011 organized by NABS & PRIST University at Thanjavur, Tamil Nadu.

Saraswathi, M.S., Uma, S., Backiyarani, S., Punniakotti, E. and Kannan, G. received 'Best Poster Award' for the research paper entitled 'Preliminary screening of induced mutants of cv. Rasthali using PCR based markers' in Global Conference on banana held on 10 -13, December 2010 at Trichy, Tamil Nadu, India.

Shiva, K.N., Mayil Vaganan, M. and Mustaffa, M. M. received 'Best Poster Award' for the research paper entitled 'Quality evaluation of banana varieties for specific target groups" in the 4th interactive workshop on biotechnological applications for sustainable development held on 12-13 March 2011, organized by NABS & PRIST University at Thanjavur, Tamil Nadu.

Uma, S. has received the "Recognition Award" for *Musa* Genetic Resource Management during the Global Conference on banana held on 10 to 13, December 2010 at Trichy, Tamil Nadu, India.

Uma, S., Lakshmi, S., Saraswathi, M.S., Akbar, A. and Mustaffa, M. M. received the 'Best Poster Award' for the research paper entitled 'Refining the protocol for zygotic embryo culture in banana hybrids' in Global Conference on Banana held on 10 to 13, December 2010 at Trichy, Tamil Nadu, India.

Dr. S. Uma receiving the "Recognition Award" for *Musa* Genetic resource management during the Global Conference on Banana


Dr. M. S. Saraswathi receiving the Best Poster Award during the Global Conference on Banana

## Recognitions

Backiyarani, S. nominated for conducting the qualifying viva-voce examination for the II M.Sc. (Ag) students of Dept. of Plant Breeding & Genetics, Agricultural College and Research Institute (TNAU) from 14.2.2011 to 15.2.2011.

Backiyarani, S. recognized as a member of the Doctoral Committee for three Ph.D scholar of the Bharathidasan University, Tiruchirappalli.

Backiyarani, S. recognized as country member of prestigious Global *Musa* Genomics Consortium (GMGC), France.

Backiyarani, S. recognized as external examiner for evaluation of thesis of M.Sc (Plant Breeding and Genetics) Scholar TNAU, Coimbatore.

Backiyarani, S. was reviewer of the project proposal entitled "Socio economic improvement of rural women through biotechnological approach: Micro propagation of banana" which was forwarded from Department of Scientific and industrial Research, New Delhi.

Padmanaban, B. nominated as Joint Secretary of AIPUB, Tiruchirapalli.

Padmanaban, B. nominated as a Co-guide for guiding Sri. C.Sankar, M.Sc., (Agrl. Entomolgy), Krishi Vigyan Kendra, Peram balur under Annamalai University, Annamalai Nagar.

Padmanaban, B. nominated as an examiner by the Bharathiar University, Coimbatore and conducted Ph.D., Viva-voce for Mr.K.Perumal samy on 15th November 2010 at UPPASI Tea Research Institute, Nirar Dam, Tamil Nadu.

Saraswathi, M.S. recognised as a Doctoral Research Committee Member for guiding Ms.P. Gangadevi for doing Ph.D research at the Pathology lab of NRCB, Trichy.

Saraswathi, M.S. recognized as Research Adviser for guiding Ph.D (Biotechnology) students of Bharathidasan University, Tiruchirapalli.

Selvarajan, R. nominated as external examiner for evaluation of M.Sc (Agri) thesis, TNAU, Coimbatore.

Selvarajan, R. nominated as the member of organizing committee of Indian Phytopathology Society (IPS) - Southern Zone and the member of evaluation committee for the selection of candidates for M.J.Narashimhan award during the symposium on "Changing plant disease scenario in relation to climate zone" during 30th & 31st July 2010 held at ISSR, Calicut, Kerala.

Selvarajan, R. recognized as one of the reviewers for an international journal "Virus genes" and for an "Indian Journal of Virology" to review the research articles.

Sundararaju, P. nominated as the member of Institute Management Committee of Directorate of Oil Palm Research, (DOPR), Pedavegi, Eluru, Andhra Pradesh.

Thangavelu, R. recognized as one of the reviewers for an international journal of "Plant Disease" and "Plant Pathology" to review research articles.

Uma, S was invited as banana taxonomic expert to finalize the classification of Pacific bananas involving Moia, Popuolu, Moia- Popuolu and Fei bananas of Asia and Pacific.

Uma, S. has acted as convener for the session on 'Breeding of banana and plantains' during the Global Conference on 'Meeting the challenges in banana and plantain for emerging biotic and abiotic stresses' organized by AIPUB and NRCB, Trichy, held at Hotel Sangam, from 10-13, December, 2010.

Uma, S. has acted as Convener for the workshop on 'Conservation strategies for *Musa* germplasm during the Global Conference on 'Meeting the challenges in banana and plantain for emerging biotic and abiotic stresses' organized by AIPUB and NRCB, Trichy, held at Hotel Sangam, from 10-13, December, 2010.

Uma, S. recognized as a member and Co-Chair of the 'Working Group 1: Genetic diversity, gap filling, taxonomy and characterization' of the Global MusaNet programme.

Uma, S. recognized as the 'Accredited Lab for Genetic Fidelity Testing' of tissue cultured banana plants by the DBT, New Delhi, India for the period of 2011- 2013.

Uma, S. recognized as the country member of prestigious 'Global Musa Genomics Consortium', France.

Uma, S. recognized as University nominee for the 'Institute Biosafety Committee (IBSC)' of the Bharathidasan University, Trichy, Tamil Nadu.

## 9 LINKAGES AND COLLABORATIONS IN INDIA AND ABROAD

- NRC for Banana has been recognized as a member of GMGC which provides access to large number of data available across the Musa working in the globe and available in the public domain
- NRC for Banana has collaborated with Bioversity International, France and QDPI, Australia for conducting a ring test for validating the indexing protocol for banana viruses
- NRC for Banana has collaborated with eight co-ordinating/optional centers under AICRP on Tropical Fruits, IIHR (ICAR), Bangalore for evaluation of different varieties of bananas for fiber extraction
- NRC for Banana has collaborated with CTCRI, Trivandrum (Kerala) and CPRI, Shimla (H.P.) for development of extruded product by blending banana, cassava and potato flours

# 10 PUBLICATIONS

## Research Papers


Jeyabaskaran, K.J. and Mustaffa, M.M. 2010. Integrated nutrient management in banana. *Indian Journal of Fertiliser*. 6 (11): 24-31.

Sangeetha, G., Thangavelu, R. and Usha Rani, S. 2010. Evaluation of plant oils for suppression of crown rot disease and improvement of shelf life of banana (*Musa* spp. AAA subgroup, cv.Robusta) *International Journal of Food Science and Technology*. 45: 1024-1032.

Sangeetha, G., Thangavelu, R., Usha Rani, S., Muthukumar, A. and Udayakumar, R. 2010. Induction of systemic resistance by mixtures of antagonist bacteria for the management of crown rot complex on banana. *Acta Physiology Plantarum*. 32: 1177-1187.

Saraswathi, M.S., Uma, S., Prasanya Selvam, K., Ramaraj, S., Durai, P. and Mustaffa, M.M. 2011. Assessing the robustness of IRAP and RAPD marker systems to study intra group diversity among Cavendish (AAA) clones of banana. *Journal of Horticulture Science and Biotechnology*. 86 (1): 7-12

Selvarajan, R., Balasubramanian, V., Dayakar, S., Sathiamoorthy, S. and Ahlawat, Y.S. 2010. Evaluation of immunological and molecular techniques for the detection of different isolates of banana bunchy top virus in India. *Indian Phytopath*. 63 (3): 333-336.

Selvarajan, R., Mary Sheeba, M. and Balasubramanian, V. 2011. Simultaneous detection of episomal banana streak mysore virus and banana bunchy top virus using multiplex RT-PCR. *Current Science*. 100 (1): 1031-34.

Selvarajan, R., Mary Sheeba, M., Balasubramanian, V., Rajmohan,. R., Lakshmi Dhevi, N. and Sasireka, T. 2011. Molecular Characterization of Geographically Different Banana Bunchy Top Virus (BBTV) Isolates in India. *Indian J. Virol.* 21(2): 110-116.

Sundararaju, P. 2010. Identification of nematode resistant gene sources against root-lesion nematode (*Pratylenchus coffeae*) in banana. *Indian Journal of Nematology*. 40: 48-54.

Sundararaju, P. and Kiruthika, P. 2009. Effect of bio-control agent, *Paecilomyces lilacinus* along with neemcake and botanicals for the management of *Meloidogyne incognita* on banana. *Indian Journal of Nematology*. 39: 201-206.

Thangavelu, R. and Mustaffa, M.M. 2010. A potential isolate of *Trichoderma viride* NRCB-1 and its mass production for the effective management of Fusarium wilt disease in banana. *Tree and forestry science and biotechnology*. 4: 76-84.

Thangavelu, R. and Mustaffa, M. M. 2010. First Report on the Occurrence of a Virulent Strain of Fusarium Wilt Pathogen (Race-1) Infecting Cavendish (AAA) Group of Bananas in India. *Plant Disease*. 94: 1379.

Uma S., Lakshmi, S., Saraswathi, M. S., Akbar, A. and. Mustaffa, M. M. 2010. Embryo rescue and plant regeneration in banana (*Musa* spp.). Plant Cell Tissue and Organ Culture. 105(1): 105-110.


## Popular articles


Anuradha, C. 2010. Biosafety regulations in India. ***In:*** souvenir of the "National Conference on Biosaftey for Health" held at H.H. The Rajah's Govt. College, Pudukottai, Tamil Nadu during 1.10.2010.

Backiyarani, S., Uma, S. and Saraswathi, M.S. 2010. *Musa* genome sequencing: Current status and future perspectives. **In**: Souvenir of the Global Conference on Banana on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" held at Tiruchirapalli, Tamil Nadu, India during 10-13, December, 2010. pp. 20-24.

Jeyabaskaran, K.J. and Mustaffa, M.M. 2010. Importance of sulphur in banana cultivation. **In**: Souvenir of the Global Conference on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses", during 10-13 Dec., 2010 at Trichy. pp. 41-44.

Kumar, V. and Mustaffa, M.M. 2010. 'Improved pre-harvest cultivation practices for ensuring high quality bunch for domestic and export markets'. **In:** Souvenir of the Global Conference on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" during 10-13, December 2010 held at Tiruchirapalli, Tamil Nadu. pp. 52-55.

Mayil Vaganan, M., Shiva, K. N., Ravi, I. and Mustaffa, M. M. 2010. Wealth generation from waste: Banana fibre, Paper and fuel. **In:** Souvenir of the Global Conference on "Meeting the Challenges in Banana and

Plantain for Emerging Biotic and Abiotic Stresses" during 10-13 December, Tiruchirappalli, Tamil Nadu. pp. 75-80.

Mayil Vaganan, M. and Shiva, K. N. 2010. Banana to feed and keep healthy. *Ind. Hort.*, 55: 10-12.

Padmanaban, B. and Mustaffa, M. M. 2010. Semiochemicals - An eco-friendly control strategy for insect pests of Banana. **In:** Souvenir of the Global conference on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" held at Tiruchirapalli during 10-13 December 2010. pp. 50-51.

Ravi, I. and Mayil Vaganan, M. 2010. Overcoming abiotic stresses in banana. *Indian Horiculture.* 55: 15-17.

Ravi, I. and Mustaffa, M. M. 2010. Ripening bananas the natural way. *Indian Horticulture*. 55: 8-9.

Ravi, I. and Mustaffa, M. M. 2010 Impact of climate change on Banana. **In** : Souvenir of the Global Conference on Banana- Meeting the Challenges in on banana and plantation for emerging biotic and abiotic stresses, 10-13 December 2010, Tiruchirapalli, organized by AIPUB & NRCB, Tiruchirapalli, Tamil Nadu, pp. 45-49

Saraswathi, M. S. and Uma. S. 2011. New advances for production of disease free planting material in banana. **In:** Proceedings of the National consultation meeting on Production disease free quality planting material propagated through tubers and rhizomes held at CPRI, Modipuram, Meerut between 4-5, March 2011. pp. 156-162.

Saraswathi, M. S., Uma. S. and Backiyarani, S. 2010. DNA barcoding in *Musa* - Applications and limitations. In: Souvenir of the Global Conference on Banana held at Tiruchirapalli, Tamil Nadu, India during 10-13, December, 2010. pp. 31-35.

Selvarajan, R. and Mustaffa, M. M. 2010. Managing banana viruses for conservation of banana biodiversity and increased productivity. **In :** Souvenir of the Global conference on "Meeting the challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" held at Trichy, Tamil Nadu during 10 - 13th December, 2010. pp. 60-64.

Selvarajan, R., Anuradha, C. and Mustaffa, M. M. 2010. Transgenic approaches for virus resistance in banana. In souvenir of the Global conference on "Meeting the challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" held at Trichy, Tamil Nadu during 10-13th December, 2010. pp 65-69.

Selvarajan, R. and Mustaffa, M. M. 2010. Hill banana to combat viral problem. *Indian Horticulture.* pp. 18-20.

Selvarajan, R. 2010. Onsite disease detection kits for banana. *Indian Horticulture*. pp. 13-14.

Selvarajan, R. 2011. Serodiagnosis, ELISA and different formats. **In**: Manual of NAIP sponsored training on Molecular diagnostic for pathogens infecting crop plants organized at CTCRI, Sreekaryam, Thiruvananthapuram, during 16-25, Feb'11 sponsored by NAIP, ICAR, New Delhi. pp. 30-36.

Selvarajan, R. 2011. Isolation of nucleic acids from infected plants basics and trouble shooting. **In**: Manual of NAIP sponsored training on Molecular diagnostic for pathogens infecting crop plants organized at CTCRI, Sreekaryam, Thiruvananthapuram, during 16th to 25th Feb.2011. pp. 30-36.

Selvarajan, R. 2011. Polymerase chain reaction - basics and different formats. **In**: Manual of NAIP sponsored training on Molecular diagnostic for pathogens infecting crop plants organized at CTCRI, Sreekaryam, Thiruvananthapuram, during 16th to 25th Feb. 2011. pp. 97-104.

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Shiva, K. N., Mayil Vaganan, M. and Mustaffa, M. M. 2010. Value addition in Banana - A Potential enterprise. In: Souvenir of the Global Conference on Banana- Meeting the Challenges in on banana and plantation for emerging biotic and abiotic stresses, 10-13 December, Tiruchirappalli, organized by AIPUB & NRCB, Tiruchirappalli, Tamil Nadu. pp. 70-74.

Sundararaju, P., Kumar, V. and Mustaffa, M. M. 2010. Enhancing profitability in high Tiruchirapalli, Tamil Nadu. pp. 52-55.

Uma, S. and Saraswathi, M. S. 2010. Banana Udhayam - a boon to farmers. Indian Horticulture. Spl. Supplement on Banana. Cover III.

Uma, S., Saraswathi, M.S. and Backiyarani, S. 2010. Application of proteomic studies in banana - perspectives and precincts. **In**: Souvenir of the Global Conference on Banana held at Tiruchirapalli, Tamil Nadu, India during 10-13, December, 2010. pp. 25-30.

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Blomme, G., Eden-Green, S., Mustaffa, M. M, Nwauzoma, B., Thangavelu, R. 2010. Major Diseases of Banana. Pages, 85-120, ***In:*** Banana Breeding -Progress and Challenges Eds. Michael Pillay and Abdou Tenkouano. CRC press (Taylor and Francis group) New York. pp. 363.

Mustaffa, M. M. and Ravi, I. 2010. Impact of climate change on adaptation of Banana varieties. ***In:*** Impact of climate change on Fruit crops. Eds. W.S. Dhillon and P.S. Aulakh. Narendra Publishing House, Delhi, India. pp. 349-56.

Padmanaban, B and Mustaffa, M. M. 2011 Pheromone: Its use in Banana. In: Pheromone Research in India . (eds.) Nandagopal et.al; .AAZRA, CRRI, Cuttack. pp. 125-140.

Padmanaban, B. and Mustaffa, M. M. 2011. Biorational pest management in Banana. Proc.of the advanced training programme on Biorational Pest Management.TNAU, Coimbatore. pp. 110-115.

Ravi, I. and Uma, S. 2011. Phenotyping banana and plantains for drought. ***In:*** Drought Phenotyping in Crops: From Theory to Practice. CGIAR Generation Challenge Programme (GCP), c/o CIMMYT, Apdo Postal 6-641, 06600 México. pp. 417-430.

Ravi, I. and Mustaffa, M. M. 2010. Impact analysis of temperature rise and elevated carbondioxide on banana production in India. ***In:*** Challenges of Climate change - Indian Horticulture. Eds: H.P.Singh, J.P.Singh and S.S.Lal. Westville Publishing House, New Delhi. pp. 42- 48

Ravi, I. and Mustaffa, M. M. 2010. Impact of climate change on Growth and evelopment of Banana. In: Impact of climate change on Fruit crops. Eds. W.S. Dhillon and P.S. Aulakh. Narendra Publishing House, Delhi, India. pp. 87-94.

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Shiva, K.N., Mayil Vaganan, M. and Mustaffa, M.M. 2011. Basic Principles and Methods of Preservation/Processing. In: Training Manual on Value-added Products from Banana Eds. K.N. Shiva, M. Mayil Vaganan and M.M. Mustaffa). Published by the Director, National Research Centre for Banana, Trichy, Tamil Nadu, pp. 10.

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added Products from Banana (Eds. K.N. Shiva, M. Mayil Vaganan and M.M. Mustaffa). Published by the Director, National Research Centre for Banana, Trichy, Tamil Nadu, pp. 11 - 12.

Shiva, K.N., Mustaffa, M.M. and Mayil Vaganan, M. 2010. Extraction of Banana Fiber and Production of Handicrafts. In: Training Manual on 'Extraction of Banana Fiber and Production of Handicrafts' Ed. Shiva. K.N. Published by the Director, National Research Centre for Banana, Trichy, Tamil Nadu, pp. 1-16.

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Uma, S., Saraswathi, M.S., Rekha, A. and Ravishankar, K.V. 2010. Banana and Plantains. In: Advances in Horticulture Biotechnology - Molecular Markers and Marker Assisted Selection - Fruit Crops, Plantation Crops and Spices (Eds. H.P. Singh, V.A. Parthasarathy and K. Nirmal Babu ) (Volume III), Westville Publishing House, New Delhi. pp. 13-66.

Uma, S., Saraswathi, M.S. and Pillay, M. 2011. Evolution and genetic relationships in banana and plantains. diversification, taxonomy and application of molecular markers in banana and plantains. In: Banana Breeding - Progress and challenges (Eds. Pillay and Tenkouano). Volume II. pp. 21-40. Taylor and Francis Group.

## Technical bulletins

Padmanaban, B., Pandey, V. and Mustaffa, M.M. 2010 Kele ke keton ka akikruth prabandhan, Thakniki bulletin # 17 , National Research Centre for Banana, Tiruchirapalli- 620 102 . pp 13.

Padmanaban, B. and Mustaffa, M.M. 2010 Integrated Management of Pests of Bananas and Plantains , Technical bulletin # 9 , National Research Centre for Banana, Tiruchirapalli- 620 102 . pp 17.

Shiva, K.N., Ravi, I., Mayil Vaganan, M. and Mustaffa, M.M. 2011. Training Manual on Post Harvest Handling, Packing, Storage and Ripening in Banana for Domestic and Export Markets" to the Exporter/ Entrepreneur, 7-9 March 2011. Published by the Director, National Research Centre for Banana, Trichy, Tamil Nadu. pp. 59.

Shiva,K.N., Mustaffa, M.M. and Uma, S. 2011. Protection of Plant Varieties and Farmers' Rights (PPV & FRA) and Copy Rights. National Research Center for Banana, Trichy, Tamilnadu. pp. 26.

Sundararaju, P. and Mustaffa, M.M. 2010. Nematode Management in Banana and Plantains. Technical Bulletin No.10 NRC for banana. pp.22.

Uma, S., Sajith, K.P., Saraswathi, M.S. and Durai, P. 2010. Macropropagation - A farmer friendly technology. Tech. Bull. No 18. pp. 17.

## Extension/Technical folders

Anuradha, C. and Mustaffa, M. M. 2010. Multiplex-PCR for simultaneous detection of four major banana viruses. NRCB - Technical folder No. 1.

Anuradha, C. and Mustaffa, M. M. 2010. Banana health based products- baby food, health drink and soup mix. NRCB - Technical folder No. 3.

Jeyabaskaran, K. J. and Mustaffa, M. M. 2010. Banana Sakthi - A Micro Nutrient Mixture. NRCB - Technical folder No. 2

Shiva, K. N., Ravi, I., Mustaffa, M. M. and Mayil Vaganan. M. 2010. Ethylene - A Safe Ripening Agent for Banana. NRCB - extension folder No. 17.

## Contributions made in compilation/ documentation

- Jeyabaskaran, K. J., Ravichamy, P. and Mustaffa, M. M. 2010. "NRCB at a Glance". A 10 minute video film document in English.

- Jeyabaskaran, K. J., Ravichamy, P. and Mustaffa, M. M. 2010. "NRCB at a Glance". A 10 minute video film document in Tamil.
- Pandey, V., Mustaffa M. M. Jeyabaskaran, K.J. and Ravichamy, P. 2010 "NRCB at a Glance" A 10 minute video film document in Hindi.

## Papers presented in Conferences/ Symposia/ Seminars/ Workshops/ Meeting, etc.

### International

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Backiyarani, S., Uma, S., Arunkumar, G., Saraswathi, M.S. and Sundararaju, P. 2010. Identification and characterization of nematode resistance gene(s) through SSH approach. ***In:*** Global Conference on Banana held at Tiruchirapalli, Tamil Nadu, India during 10-13, December, 2010. pp 17.

Muthusamy, M., Uma, S., Saraswathi, M.S. and Backiyarani, S. 2010. Preliminary studies on Musa proteome response against drought stress. ***In:*** Global Conference on Banana held at Tiruchirapalli, Tamil Nadu, India during 10-13, December, 2010. pp 37.

Sajith, K.P., Uma, S., Saraswathi, M.S. and Durai, P. 2010. Effect of plant hormones in macropropagation for improved build proliferation in superior Silk clone-Bangladesh Malbhog. ***In:*** Global Conference on Banana held at Tiruchirapalli, Tamil Nadu, India during 10-13, December, 2010. pp. 50.

Saraswathi, M.S., Uma, S., Kannan, G., Azeera, M. and Durairaja, S. 2010. Improvement of banana through mutagenesis:Determination of the LD50 of physical and chemical mutagens for banana shoot tips. ***In:*** Global Conference on Banana held at Tiruchirapalli, Tamil Nadu, India during 10-13, December, 2010. pp 32.

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## Invited talk/ Lead Lecture

The following Scientists have given lead lecture/ invited talk during the global Conference on banana "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" which was held at Hotel Sangham, Tiruchirapalli, Tamil Nadu. during 10-13, December 2010.

| Name of the Scientist | Title |
|---|---|
| Dr. M.M.Mustaffa | Status of Banana research in India |
| Dr. P. Sundararaju | An overview of banana research on plant parasitic nematodes in India |
| Dr. B. Padmanaban | New strategies for pest management in Banana |
| Dr. S. Uma | On nutritional diversity available in the Musa germplasm and its significance to the benefit of posterity through fortification. |
| Dr. R. Thangavelu | New approaches for the eco-friendly management Fusarium wilt and Sigatoka diseases of banana |
| | New advances in wilt disease management in banana |
| Dr. V. Kumar | Improved production technology in banana |
| Dr. R. Selvarajan | Use of molecular diagnostic kits in the elimination of viruses in the production of disease free planting material of banana |
| Dr. I. Ravi | Physiological and bio-chemical indicators associated with abiotic stresses in banana |
| Dr. S. Backiyarani | Importance of transcriptomic studies in banana and the expression of genes under different stress conditions |
| Dr. K.J.Jeyabaskaran | Nutrient dynamics in banana cultivation |

# 11 CONSULTANCY SERVICES AND COMMERCIALISATION OF TECHNOLOGIES

- Technical consultancy project on 'Development of tissue culture protocol for the multiplication of banana variety Sabri' costing Rs. 2.76 lakhs has been approved and initiated at HRC, Nagicherra, Tripura
- Technologies of three value added products of banana viz. Flower pickle, Banana Flour and banana Soup-mix have been transferred to M/s ROAD Development Trust (SHG), Tirunelveli, Tamil Nadu.
- The technologies for the preparation of Banana flower pickle was transferred to 'Mangal' and 'Laxman' of Namakkal and Trichy district, respectively.
- Lab Accreditation Facility for Virus indexing and Genetic fidelity testing of tissue culture plants' analysed Robusta and Grand Naine, samples supplied by 10 different tissue culture companies for their genetic fidelity using SSR and ISSR markers and issued reports for the same.
- Technical Consultancy project on 'Development of tissue culture protocol for the multiplication of banana variety Sabri' costing Rs. 2.76 lakhs has been approved and initiated at HRC, Nagicherra, Tripura

### Resource generation through contract service- virus testing in banana

A total of 11349 samples of tissue culture plants and mother plants sucker from 29 tissue culture industries. Under this contract services, NRCB has earned an amount`22,60,519/- during this financial year.

In addition to virus testing, polyclonal antisera produced for CMV and BBTV were sold to tissue culture companies and also to the SAUs viz., TNAU, KAU and APHU. From this service, NRCB has earned an amount of Rs. 60,000/-.

# 12 RAC / IMC / IRC MEETINGS

### RAC Meeting

Research Advisory Committee (RAC) meeting of the Centre was conducted during 9th and 10th December, 2010, wherein, all the members of RAC including the Chairman Dr. P.Rethinam, Former Executive Director, APCC, Indonesia attended the meeting. Recommendations generated from the meeting were approved by the Council.

| S.No. | Name | Position |
|---|---|---|
| 1. | Dr. P. Rethinam | Chairman |
| 2. | Dr. Y. N. Reddy | Member |
| 3. | Dr. B. M. C. Reddy | Member |
| 4. | Dr. R. Palaniappan | Member |
| 5. | Dr. K. V. Ramana | Member |
| 6. | Dr. Rema Menon | Member |
| 7. | Dr. M. M. Mustaffa | Member |
| 8. | Prof. B. Sivarama Krishnan | Member |
| 9. | Dr. P. Sundararaju | Member |
| | Secretary | |

### The followings are the salient recommendations of RAC

- Study on the low-cost alternatives for tissue culture mutation breeding in Rasthali using cell lines as explants and development of genetic linkage maps using mapping population may be carried out.
- Musa germplasm maintained in the field may be evaluated against pest and diseases with special reference to viral diseases
- A demonstration plot may be undertaken in popular commercial cultivars by adopting all the technologies developed at NRCB for defining the precision farming and General Agricultural Practices (GAP) in banana
- Studies on crop specific, stage specific and soil specific requirement for banana may be intensified in order to find out the suitable period for the application of fertilizers in banana
- The effective bio-agents identified under pot culture may be tested under field conditions against Fusarium wilt disease in endemic areas
- Dip-stick method of diagnosis for CMV may be developed and compared with commercial kits.


Dr. P. Rethinam Chairing the RAC Meeting

## IMC Meeting

The fifteenth meeting of the Institute Management Committee (IMC) was held on 31.7.2010 under the chairmanship of Dr.M. M. Mustaffa, Director, NRCB. During this meeting, the a). Revised estimate for 2010 - 2011 b) Estimate 2011 - 2012 and c) Opening of LC for importing equipments under 'plan' and scheme were discussed and recommended for approval by the Council.

Dr. M.M. Mustaffa, Director, NRCB Chairing the 15th IMC Metting

## The following Members were present

| Sl. No. | Name & Address | Position |
|---|---|---|
| 1. | Dr.M.M. Mustaffa, Director, NRCB, Trichy | Chairman |
| 2. | Dr.N. Kumar, Dean (Hort), TNAU, Coimbatore | Member |
| 3. | Shri. S. Robert Vincent, DDH, Trichy | Member |
| 4. | Dr.C.K. Narayana, Head-PHT, IIHR, Bangalore | Member |
| 5. | Dr. Sukhada Mohandos, Principal Scientist, IIHR, Bangalore | Member |
| 6. | Dr.S. Uma, Principle Scientist, NRCB, Trichy | Member |
| 7. | Dr.V. Pandey, Principal Scientist, NRCB, Trichy | Member |
| 8. | Shri. K.K. Hamza, F & AO, SBI, Coimbatore | Member |
| 9. | Prof. S. Sivaramakrishnan, M/s. Shankara Group, Trichy | Member (non-official) |
| 10. | Smt. C.Gomathi, AFAO, NRCB, Trichy | Special Invitee |
| 11. | Shri.B.Vijayakumar, AAO, NRCB, Trichy | Member Secretary |

## IRC Meeting

The Fifteenth Institute Research Council Meeting was held on 28th and 29th March, 2011 under the chairmanship of Dr. M.M.Mustaffa, Director, NRCB. The salient research achievements of previous year and technical programmes for the next year were presented by respective project leaders of the institute as well as externally funded projects. The chairman has reviewed the research achievements made under each project and gave critical inputs for refinement of the research programmes.

# 13 TRAININGS/ REFRESHER COURSE / SUMMER / WINTER INSTITUTES / SEMINARS/ CONFERENCE / SYMPOSIA / WORKSHOP ATTENDED BY THE SCIENTISTS

| Scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| M.M.Mustaffa | National Consultation on Landscape and Gardening for Aesthetic Value & Environmental Services, IIHR, Bangalore | 29-30 April, 2010 |
| | ICAR Regional Committee - VIII Meeting at Bangalore | 13-15 May, 2010 |
| | Interface Meeting of Directors / Project Coordinators of Crop Science & Horticulture Divisions of ICAR, DWSR, Jabalpur | 17-18 May, 2010 |
| | National Conference on Horticulture Biodiveristy for Livelihood, Economic Development and Health Care, Bangalore | 29-30 May, 2010 |
| | Interface Meeting with the Member - Planning Commission (Agriculture), TANUVAS, Chennai | 22nd June, 2010 |
| | Scientific Advisory Committee Meeting - CREED - KVK, Ariyalur | 24th June, 2010 |
| | ATMA - Orientation Meeting, ACRI & TNAU, Trichy | 2nd July, 2010 |
| | ICAR Institute Directors Meet, ICAR, New Delhi | 15-16 July, 2010 |
| | Scientific Advisory Committee Meeting - Rover KVK, Perambalur | 20th July, 2010 |
| | ICAR - Industry Interface Meet, New Delhi | 28-29 July, 2010 |
| | Technical Standard Committee meeting on the Use of Ethephone for Ripening of banana in cold storage - NHB-SFAC, New Delhi | 13thAug., 2010 |
| | Stakeholders Consultation Workshop on Root, Tuber, Banana (RTB) for Food Security and Income, CTCRI, Trivandrum organized by Bioversity Intl., France | 16thAugust, 2010 |
| | Discussion Meeting on the Proposal on 'Micro Nutrient Biofortification of banana for India - TOT from QUT Australia to India, DBT - BIRAP, New Delhi | 23rdAugust, 2010 |
| | State Level Workshop on Export Oriented Banana Production Sangli, M.H. | 4th Sept., 2010 |
| | PGR Export Facilitation Committee Meeting - NBPGR, New Delhi | 22ndOct., 2010 |
| | Technical Standard Committee meeting on Use of Ethephone for Ripening of banana in cold storage - NHB-SFAC, New Delhi | 23rdOct., 2010 |
| | International Coconut Conference - CPCRI, Kasaragod | 27th Oct., 2010 |
| | ICAR Institute Horticulture Institute Directors - Industry Interface Meet, IIHR, Bangalore | 10-11 Nov., 2010 |
| | Global Conference on Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses, held at Tiruchirapalli, Tamil Nadu | 10-13 Dec., 2010 |

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| | National Seminar on "Climate Change and Food Security: Challenges and Opportunities for Tuber Crops" - CTCRI, Trivandrum | 20-21 Jan., 2011 |
| | Training Programme on Employers' Perspective on Labour Related Law, NAARM, Hyderabad | 17-19 Feb., 2011 |
| | ICAR Institute Directors' Conference, New Delhi | 23-24 Feb., 2011 |
| | Horticulture Division Interaction Meeting with RAC Chairs & Directors, ICAR, New Delhi | 8-9 March, 2011 |
| P. Sundararaju | The National Consultation Group Meeting on Landscape Gardening for Aesthetic Values and Environmental Services, held at IIHR, Bangalore | 29-20, April, 2010 |
| | National Conference on Horticultural biodiversity for livelihood, economic development and healthcare held at GKVK campus, Bangalore | 28-31 May, 2010 |
| | The Institute Management Committee meeting of the Directorate of Oil Palm Research (DOPR), Pedavegi, Eluru, Andhra Pradesh. | 18, Sep., 2010 |
| | Sensitization cum training workshop for the Nodal Officers of Project Monitoring and Management System of ICAR (PIMS-ICAR), NAARM, Hyderabad | 24-25, Oct., 2010 |
| | Global Conference on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses", held at Tiruchirapalli, TN | 10-13, Dec., 2010 |
| | Sensitization Meeting of Nodal Officers for preparation of Results Framework Document (RFD), NAS Complex, New Delhi | 11-14,Mar., 2011 |
| B. Padmanaban | Farmers meeting at Periyapallam, Cuddalore organized by KR Foundation. | 12.4.2010 |
| | International conference on Coconut Biodiversity for Prosperity, CPCRI, Kasaragod, Kerala, | 25-28 0ct., 2010 |
| | Sensitization training workshopon Bioinformatics and its various applications under NAIP -NBIG Project, NBAII, Bangalore | 8-12 Dec., 2010 |
| | Global conference on "Meeting challenges in Banana and plantain for emerging biotic and abiotic stresses", Tiruchirapalli | 10-13 Dec., 2010 |
| S. Uma | Global Conference on "Meeting the challenges in banana and plantain for emerging biotic and abiotic stresses", held at Tiruchirapalli, TN | 10-13 Dec., 2010 |

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| | Musa Net strategy meeting held at Agropolis International, organized by BIOVERSITY- France, Montpellier, France | 28 - 03 Mar.,2011 |
| | Taxonomic Advisory Group expert to work on classification of Pacific bananas and Plantains held at BIOVERSITY- France, Montpellier, France | 4-5th March 2011 |
| | Coconut Biodiversity for Prosperity organized by CPCRI, Kasargod, Kerala | 25-28th Oct. 2010 |
| | Annual review meeting of the NPTC- functional genomics project | 19-20thMay 2010 |
| | The review and discussion meeting of the externally funded project on Regeneration of priority Musa accessions with Dr. Ann Vezina, BIOVERSITY, France | 5th-8th July 2010 |
| | Interactive session on biotechnology research in ICAR held at NASC complex, New Delhi | 26th-27thJul. 2010 |
| | Discussion and Orientation training programme for officers from Tripura, sponsored by PPV& FRA, New Delhi | 21-23 Sept. 2010 |
| | Interaction meeting with CIRAD scientists on the possibilities of collaborated Musa research programme organized by BIOVERSITY- France, Montpellier, France | 7-8th March 2011 |
| | Doctoral Review committee meeting for two Ph.D students of Satyabhama University, Chennai | 4th Jan. 2011. |
| | The review and discussion meeting of the externally funded project on Regeneration of priority Musa accessions with Dr. Ann Vezina, BIOVERSITY, France | 5th- 8th July 2010 |
| V. Pandey | ICAR-Industry Interface meet at NASC, New Delhi | 28-29th July 2010 |
| | An Off Campus Training- cum- State Level Workshop on Export Oriented Banana Production organized by Maharashtra State Horticulture and Medicinal Plant Board at Sangli, Maharashtra. | 4th Sep. 2010 |
| I. Ravi | Orientation training cum workshop as a nodal officer of Hub-8 for consortia-based NAIP research project organized by NAARM, Hyderabad | 16-17th June 2010 |
| | NAIP sponsored Training Programme on SAS statistical programme for trainers conducted by NAARM, Hyderabad | 28th May to 2nd August 2010 |

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| | On Impact of Climate Change on Fruit Crops, (ICCF-2010) organized by Punjab Agriculture University, Ludhiana. | 6- 8th Oct. 2010 |
| | Global Conference on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" organized by AIPUB & NRC for Banana, Tiruchirapalli | 10-13, Dec., 2010. |
| R.Thangavelu | Farmers meeting held at Periyapallam, Cuddalore organized by KR Foundation | 12th April 2010 |
| | Field day (Kissan mela) organised at NRCB | 21st Aug. 2010 |
| | Fungal disease diagnostics and Important diseases of banana and their management for M.Sc (Plant pathology) students and B.Sc (Agri) students of Agricultural college and research Institute (TNAU), Madurai | 28th Sep. 2010 |
| | Global conference on Meeting the challenges in Banana and Plantain for emerging biotic and abiotic stresses the Tiruchirapalli, TN | 10-13th Dec. 2010 |
| | National symposium on Molecular approaches for management of fungal diseases of crop plants, Indian Institute of Horticultural Research, Hessaraghatta, Bangalore | 27-30th Dec. 2010 |
| | UGC sponsored National seminar on recent advances in plant disease research, faculty of Agriculture, Annamali University Chidambaram | 25th-26thFeb. 2011 |
| R. Selvarajan | International training on Molecular diagnostics at DSMZ, Braunschweig, Germany | 17th Mar. 2010 to 16th June 2010 |
| | Seminar on Role of transgenic in shaping Indian Agriculture organized by Indian Virological Society at Plant Virology Unit, IARI, New Delhi | 23rd July 2010. |
| | "DBT- transgenic project review meeting on Development of virus resistant transgenic in crops" held at New Delhi | 21st July 2010 |
| | Field day (Kissan Mela) organized at NRC for Banana | 21st Aug. 2010 |
| | National symposium on "Changing plant disease scenario in relation to climate zone" conducted by Indian Phytopathology Society (Southern Zone), ISSR, Calicut, Kerala | 20th & 21st Oct 2010 |
| | International Coconut conference held at CPCRI, Kasaragod | 24-28th Oct., 2010 |
| | Global conference on "Meeting the challenges in Banana and plantain for emerging biotic and abiotic stresses" held at Tiruchirapalli, Tamil Nadu | 10-13th Dec., 2010 |

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| | A meeting of in-charge of ATL under NCS-TCP at IARI, New Delhi. | 24th Jan., 2011 |
| | National consultation on production of quality planting material propagated through tubers and rhizomes, CPRI Campus, Modhipuram, Meerut | 4-5 March, 2011. |
| | Fourth interactive workshop on Biotechnological application for sustainable development, PRIST University, Thanjavur. | 11-12 Mar., 2011 |
| V. Kumar | Banana Show cum Workshop' organized by the Ernakulam District Agri-Horti Society at Kochi, Kerala. | 30 Apr.-2nd May 2010 |
| | National Conference on "Horticultural biodiversity for livelihood, economic development and healthcare" held at GKVK campus, Bangalore | 28-31, May, 2010. |
| | XVI Scientific Advisory Committee Meeting of Cuddalore Dist. Krishi Vigyan Kendra (KVK), at Regional Research Station (TNAU), Vriddhachalam | 27th Sep.2010. |
| | International Conference on "Coconut Biodiversity for Prosperity" held at CPCRI, Kasaragod during | 25-28, Oct.,2010 |
| | Global Conference on Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses, Hotel Sangam, Tirchy, Tamil Nadu | 10-13, Dec., 2010 |
| | Improved production and postharvest technologies including and value addition in banana" for the officials of Ministry of Agriculture and Forestry, Government of Commonwealth of Dominica, Roseau, Dominica | 28-12-2010 to 12-01-2011 |
| | Antioxidant phytonutrients and volatile flavours in horticultural crops, Division of Physiology and Biochemistry, IIHR, Bangalore. | 15-24, Sep.,2010 |
| | Nutritional and medicinal values of banana in the MTC on Postharvest technology and value added products in banana | 24th Oct., 2010 |
| | Global Conference on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses", AIPUB & NRC for Banana, Tiruchirapalli. | 10-13, Dec., 2010. |
| K.J.Jeyabaskaran | Global Conference on Meeting the challenges in Banana and plantain for emerging biotic and abiotic stresses", Trichy. | 10-13, Dec., 2010 |
| | Interactive Meeting on Nutrient Dynamics in Horticultural Crops at National Research Centre for Citrus, Nagpur. | 27-28th Sep., 2010 |

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| S.Backiyarani | Workshop for the consortia - based research project Strengthening statistical computing for NARS for SAS installation programme held at National Academy of Agricultural Research Management, Hyderabad. | 6-17, June 1, 2010. |
| | Annual review meeting on network project on transgenic crops held at NRCPB, New Delhi | 19-20th May, 2010 |
| | One day Bioinforamtic Meet held at NBPGR, New Delhi | 7th Aug., 10 |
| | Training programe in the field of Marker Assisted Selection under NAIP programme at Clemson University, Clemson, South Carolina | 16th Aug. to 15th Nov., 2010 |
| | Interactive meeting with DG, ICAR on Information and Communication Technology at NASC, New Delhi | 3-4th Nov., 2010 |
| | Global Conference on Banana, Tiruchirapalli, Tamil Nadu | 10-13, Dec., 2010 |
| | Annual review meeting on the project entitled on Framing crop specific DUS Guidelines PPV&FR, NAS Complex, New Delhi | 25th Feb.2011. |
| K.N.Shiva | ICAR-Industry Meet 2010, at NASC Complex, New Delhi | 28-29 July 2010 |
| | Workshop on Integrated Food Law at Puducherry University | 3rd Sep., 2010 |
| | Workshop on Crop Production and Post harvest handling in Banana, organized by Dept of Horticulture, Burhanpur at Burhanpur, M.P | 10th October 2010 |
| | Conference on Challenges and Way Forward for Agricultural Products Export, organized by APEDA & CII at Hotel Le Royal Meridien, Chennai | 10th Nov., 2010 |
| | Horticulture-Industry Meet, organized by IIHR & ZBTU, Bangalore at IIHR, Bangalore | 11th Nov. 2010 |
| | Global Conference on Meeting the Challenges in banana and plantation for emerging biotic and abiotic stresses, held at Tiruchirappalli, TN | 10-13 Dec., 2010 |
| | Workshop on Quality Banana Fiber Extraction and Information System to the Farmers under MAHIMA with the financial support of NABARD at Saraswathi Krishi Vigyan Kendra, Puletheri, Karur Dt. | 22ndJan., 2011 |
| | Scientist and Farmers' interface meeting in the 3rd Agri Expo, organized by Dhinamalar at National College High School ground, Trichy. | 30th Jan., 2011 |
| | Awareness cum Training Programme on Protection of Plant Varieties and Farmers' Rights held NRC Banana, Tiruchirappalli, Tamil Nadu. | 10th Feb.,2011, |

| | | |
|---|---|---|
| | 4th Interactive Workshop on Biotechnological Applications for Sustainable Development, organized by NABS (Chennai) & PRIST University at Thanjavur, Tamil Nadu | 12-13thMar. 2011 |
| | Scientific Advisory Committee Meeting of KVK (Nominated Member), Veterinary College & Research Institute (TANUVAS) at Namakkal, Tamil Nadu | 24th March 2011 |
| M.S. Saraswathi | National consultancy meeting on Agro-biodiversity held at NASC, New Delhi | 26-27, May 2010 |
| | Review meeting of externally funded projects, NARS Complex | 16th Oct. 2010 |
| | Review meeting of the DBT - ATL, Division of Plant Pathology, IARI, New Delhi | 24th Jan. 2011 |
| | Review meeting of the DBT - ATL, CDFD, Hyderabad. | 25th Feb. 2011 |
| | National consultation meeting on Production of disease free quality planting material propagated through tubers and rhizomes at CPRI, Modipuram, Meerut | 4-5, March 2011 |
| C. Anuradha | Review meeting of the DBT network project - Development of virus resistant transgenic crops: Development of transgenic hill banana resistant to BBTV (replicase gene mediated), Virology Division, at IARI | 7 & 8, April, 2010 |
| | ICAR Industry Meet, 2010, NASC complex | 28-29 July 2010 |
| | Review meeting of ICAR Network project on transgenic in crops- transgenic component held at NRCPB | 9& 11, Sep., 2010 |
| | National Conference on Biosafety for Health at H. H. Rajah's Govt. College, Pudukottai | 1.10.2010 |
| | Horticulture Industry Meet, 2010, IIHR, Bangalore | 11th-12thNov. 2010 |
| | Global Conference on "Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" held at Trichy, Tamil Nadu | 10-13thDec., 2010. |
| | Annual Meeting-Cum-Workshop, 2010-11 on 'Zonal Technology Management and Business Planning and Development Perspective of ICAR' held at CIFT, Cochin. | 5th March, 2011 |

# 14 SEMINARS/ MEETINGS/ WORKSHOPS/ CONFERENCES/ SUMMER INSTITUTES AND FARMERS TRAINING ORGANIZED AT THE CENTRE

## Global Conference on Banana

A Global Conference on "Meetings the challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses" was organized joinly by the Association for the improvement of Production and Utilization of Banana (AIPUB) and the National Research Centre for Banana (NRCB) was held at Tiruchirapalli, Tamil Nadu during 10-13 December 2010.

D r. D.P. Ray Vice Chancellor OUAT, Bhuwaneshwar, Orissia, lighting the lamp to inagurate the Global Conference on Banana


Dr.M.M.Mustaffa, Director and Organizing Secretary welcomed the gathering.

Dr. H. P. Singh, DDG (Hort.) was awarded the most prestigious "**Kadali Ratna**" award for his leadership in Horticulture and also for his contribution made in increasing the productivity and marketing of banana in India. Dr. H. P. Singh was the first person to receive this prestigious award. Dr. Stephan Weise, Programme Coordinator, Bioversity Intl., France, who was the Chief Guest, distributed various awards such as "**Kadlai Puraskar**" and "**Nalla Vazhai Award**" to Scientists and farmers.

Dr. H. P. Singh, DDG (Hort.) receiving "**Kadali Ratna**". award.

Participants at the Global Conference on Banana

Besides eight persons were also honoured as Fellows of AIPUB for their outstanding contributions to Horticulture, especially to banana. Advances in Horticulture Biotechnology edited by H. P. Sigh and many other institute publications were also released during the occasion. Dr. P. Sundararaju, proposed vote of thanks.


Publications released during Global Conference on Banana

During this four day conference, eight technical sessions, three plenary lectures and four concurrent workshops were held. Eminent scientists from various countries like Germany, Philippines, Uganda, France and England chaired various sessions and also addressed about the scenario of banana at national and international level, achievements and future strategies to increase the production and productivity of banana.

In the various technical sessions namely 1) Global and National Scenario, 2) Diversity in Banana and Plantain, 3) Production of Disease-free Planting Material, 4) Breeding for Biotic and Abiotic stresses and Qualities, 5) Genomics and Biotechnological tools, 6) Health management, 7) Production system management, 8) Pre- & post harvest management and 9) Value addition and Delivery system - marketing and trade, a total of 19 lead, 16 oral and 145 poster presentations were made. Scientists of NRCB, ICAR Institutes, SAUs and several experts presented these technical papers. Workshops on Impact of Climate Change, Eco-friendly Technologies, Gene and Genomics Conservation Technologies were also held concurrently and 16 lead talks were presented by experts. Three Plenary lectures were delivered in the Conference by eminent personalities like Dr. H. P. Singh, DDG (Hort.), ICAR on Dynamics and Co-kinetics of banana Research and Development in India, Dr. J. S. Heslop Harrison, U.K. on Genomics Initiatives in Banana and Dr. Augustin B. Molina, Regional Coordinator, Bioversity International, Philippines on Pests and Diseases Scenario of Banana in South East Asia. During the plenary lecture, Dr. H. P. Singh emphasized the necessity of banana research and development and to prepare for the future challenges.

In the open sessions, experts from different disciplines clarified the doubts raised by farmers, traders and exporters. An exhibition was also organized at the conference venue involving six Horticultural Institutes of ICAR, different input suppliers, entrepreneurs, and also the Jain Irrigation System, Jalgoan, Maharashtra.

## Kissan Mela

The National Research Centre for Banana (NRCB), Tiruchirapalli, celebrated its 17th Foundation Day on 21.08.10 by organizing a

Dr. H. P. Singh, DDG (Hort.) delivering the lead talk in the technical session in the Global Conference on Banana

Dr. H. P. Singh, DDG (Hort.) delivering the plenary session during the Global Conference on Banana

Dr. M.M. Mustaffa, Director, NRCB speaking at the Kissan Mela


Participants at the Kissan Mela

'Banana Field Day' with a theme on 'Use of bio-control agents in banana IPM'. The Field Day was organized mainly to highlight and disseminate the use of various bio-control agents developed by the Centre for the management of insect pests, fungal pathogens and nematodes in banana cultivation. In addition, improved production and postharvest technologies were also discussed. In the field day, banana researchers, agriculture & horticulture officers, progressive farmers and entrepreneurs from different banana cultivating areas of Tamil Nadu have participated and discussed about various production and protection constraints and solving them in banana. Thiru T. Soundiah, District Collector, Tiruchirappalli, Thiru J. Sekar, Joint Director of Agriculture, Tiruchirappalli and Prof. B. Sivaramakrishnan, Member, Institute Management Committee, NRCB have participated in the function. Thiru T. Soundiah, District Collector presided over the field day inaugural function and distributed the awards to the progressive banana farmers. In the technical sessions, Scientists of NRCB delivered several lectures on high density planting, fertilizer management, improved production, protection and postharvest utilization. Besides, an exhibition was also arranged to demonstrate various advanced technologies on banana production developed by NRC for Banana. Other input companies related to banana production and protection like tissue culture, fertilizers, pesticides, fungicides, bio-control agents have also participated in Kisan Mela.

## List of Trainings offered

| Sl.No. | Title of the training | Date | Participants from |
|---|---|---|---|
| 01 | Improved Production Technology including Postharvest Management and Value Addition in Banana | 19-24. 4.2010 | Kerala |
| 02 | Short-term training programme on Production of value added products from banana | 28.6 - 5.7. 2010. | Tamil Nadu |
| 03 | Improved Production and Postharvest Handling of Banana | 5 - 9.7. 2010 | Uttar Pradesh |
| 04 | Short-term training programme on Extraction of Banana Fibre and Production of Handicrafts | 12 - 14. 7. 2010. | Tamil Nadu |
| 05 | Banana Field Day | 21.8.2009 | All states |
| 06 | Improved Production and Postharvest Technology of Banana | 6 - 10.9. 2010 | Assam |
| 07 | Crop Production and Postharvest Technology of Banana | 15- 16.9. 2010 | Kerala |
| 08 | Project Orientation and Discussion for the State Govt. officials of Horticultural Research Complex, under DUS project | 21 - 24.9. 2010 | Tripura |
| 09 | One day training on Crop Production and Post harvest Management in Banana for the farmers of Mohanur, Namakkal | 22 .9.2010 | Tamil Nadu |
| 10 | Improved Production and postharvest Technologies in Banana | 4- 8 10.2010. | Kerala |
| 11 | Awareness cum Training programme on Protection of Plant Varieties and Farmers Rights Act | 10.02.2011 | Tamil Nadu |
| 12 | Short-term Training on Postharvest Handling, Packing, Storage and Ripening in Banana for Domestic and Export Markets | 7- 9. 3. 2011 | Tamil Nadu |
| 13 | Improved production and postharvest handling in banana | 14 - 19. 3. 2011 | Gujarat |


Dr. S. Kannaiyan, Former chairman NBA, Chennai delivering the chief guest address in the PPV & FR Awareness programme.

Participants of the training programme on Improved Production and post harvest technologies in banana

# 15 DISTINGUISHED VISITORS

| Sl. No. | Name & Address | Date |
|---|---|---|
| 1. | Dr.N. Kumar, Dean (Hort), TNAU, Coimbatore | 31.7.2010 |
| 2. | Thiru. T. Soundiah, District Collector, Tiruchirappalli | 21.8.2010 |
| 3. | Thiru. J. Sekar, Joint Director of Agriculture, Tiruchirappalli | 21.8.2010 |
| 4. | Dr. Stephan Winter, Plt. Pathologist DSMZ, Germany | 9.12.2010 |
| 5. | Dr.P. Rethinam, Former - ADG, ICAR, Coimbatore | 9.12.2010 |
| 6. | Dr. Y.N. Reddy, Kukat Palli, Hyderabad | 9.12.2010 |
| 7. | Dr. B.M.C. Reddy, Former Director - CISH, Lucknow | 9.12.2010 |
| 8. | Dr. R.. Palaniappan, R.T.Nagar, Bangalore | 9.12.2010 |
| 9. | Dr. H. P. Singh, DDG (Hort), ICAR, New Delhi. | 10.12.2010 |
| 10. | Dr. Stephan Weise, Programme Coordinator, Bioversity Intl., France | 10.12.2010 |
| 11. | Dr. Augustin B. Molina, Regional Coordinator, Bioversity International, Philippines | 10.12.2010 |
| 12. | Dr. J. S. Heslop Harrison, U. K. Bioversity International | 10.12.2010 |
| 13. | Dr. G.V. Thomas, Director, CPCRI, Kasaragod, Kerala | 11.12.2010 |
| 14. | Dr. M. Kochubabu, Director, DOR, Pedavegi, AP | 11.12.2010 |
| 15. | Dr. S. K. Naskar, Director, CTCRI, Trivandrum, Kerala | 11.12.2010 |
| 16. | Dr. M. Anandaraj, Project Coordinator, Spices | 11.12.2010 |
| 17. | Dr. B.P. Singh, Joint Director, CPRI, Modipuram. | 11.12.2010 |
| 18. | Dr. V.A.Parthasarathy, Director, IISR, Calicut, Kerala | 11.12.2010 |
| 19. | Prof. S. Kannaiyan, Former Vice Chancellor, TNAU, Coimbatore | 10.2. 2011 |


Dr. H. P. Singh, DDG (Hort.), ICAR, New Delhi, inaugurates the New Building for Improvement Lab at the Centre on 10.12.2010

Dr. Stephan Winter, DSMZ, Germany Visit at Virology Lab on 9.12.2010

### Farmers visit

About 3950 banana farmers, Agricultural & Horticultural officers, self help groups and students visited the Centre.

Vist of Theni district farmers' for one day training programme at NRCB, Trichy

Thirunelveli district farmers' visit to exhibition at NRCB during the exposure visit organized by Govt. of Tamil Nadu

## 16 EMPOWERMENT OF WOMEN

950 women including students, SHG and other women entrepreneurs from different parts of the country visited NRCB and learnt various technologies related to postharvest and value addition.

Horticulture students visit to NRCB

## 17 PERSONNEL

### Appointment

1. Mr. M. Bathrinath was appointed as T-3, Technical Assistant w.e. f. 4. 10. 2010.
2. Mr. M. Krishnan joined as Administrative Officer from Central Agricultural Research Institute, Andaman w. e. f. 2. 2. 2011.
3. Ms. A.U. Suja was appointed as LDC w.e. f. 11. 3. 2011

### Promotion

1. Mr. B. Vijayakumar, Asst. Admn. Officer was promoted as Administrative Officer.
2. Mr. M. Krishnamoorthy, Personal Assistant was promoted as Private Secretary w.e.f. 18.9.2010
3. Mr. R. Sridhar, Steno Gr. III was promoted as Personal Assistant w.e.f. 18.9.2010

### Transferred

Dr. K.N. Shiva joined as Senior Scientist from Indian Institute of Spice Research - Calicut w. e. f. 03. 05. 2010

### Retirement

Mr. C. Kumaran (late), Mazdoor SSG-I, retired on superannuation on 31.12.2010

## Scientific Staff

| Name | Designation |
|---|---|
| Dr. M. M.Mustaffa | Director |
| Dr. P. Sundararaju | Principal Scientist |
| Dr. B. Padmanaban | Principal Scientist |
| Dr. V. Pandey | Principal Scientist |
| Dr. S. Uma | Principal Scientist |
| Dr. I. Ravi | Senior Scientist |
| Dr. R. Thangavelu | Senior Scientist |
| Dr. R. Selvarajan | Senior Scientist |
| Dr. V. Kumar | Senior Scientist |
| Dr. M. Mayil Vaganan | Senior Scientist |
| Dr. K. J. Jeyabaskaran | Senior Scientist |
| Dr. S. Backiyarani | Senior Scientist |
| Dr. K.N. Shiva | Senior Scientist |
| Dr. M. S. Saraswathi | Scientist (Sr. Scale) |
| Mr. R. Natarajan | Scientist |
| Dr. C. Anuradha | Scientist |

## Technical Staff

| Name | Designation |
|---|---|
| Mr. S. Palanichamy | T-6 Technical Officer |
| Dr. P. Durai | T-5 Technical Officer |
| Mr. P. Ravichamy | T-4 Tech. Asst. (Journalism) |
| Mrs. T. Anitha Sree | T-4 Lab. Technician |
| Mrs. C. Sagayam Jacqueline | T-4 Computer Programmer |
| Mr. D. Ramachandramurthi | T-3 Civil Overseer |
| Mr. R. Pitchaimuthu | T-3 Field Technician |
| Mr. N. Marimuthu | T-3 Field Technician |
| Mr. V. Selvaraj | T-3 Lab. Technician |
| Mr. T. Sekar | T-3 Lab. Technician |
| Mr. K. Kamaraju | T-3 Lab. Technician |
| Mr. M. Bathrinath | T-3 Tech. Asst. |
| Mr. A. Subramanian | T-2 Driver |
| Mr. P. Mohan | T-2 Tractor Driver |
| Mr. V. Manoharan | T-2 Driver |

## Administrative, Audits & Acounts and Supporting Staff

| Name | Designation |
|---|---|
| Mr. M. Krishnan | Administrative Officer |
| Mr. B. Vijayakumar | Administrative Officer |
| Mrs. C. Gomathi | Asst. Finance & Accounts Officer |
| Mr. M. Balu | Assistant (upto 30.06.2008) |
| Mr. M. Krishnamoorthy | Personal Secretary |
| Mr. R. Krishnamurthy | Assistant |
| Mr. R. Sridhar | Personel Assistant |
| Mr. R. Neela Mega Shyamala Kannan | Steno Gr. III |
| Mrs. S. Durgavathy | Upper Division Clerk |
| Mr. M. Devarajan | Lower Division Clerk |
| Ms. A.U. Suja | Lower Division Clerk |
| **Supporting** | |
| Mr. R. Mohanraj | Mali SSG-IV |
| Mr. V. Pandiyan | Mali SSG-III |
| Mr. V. Thangaraju | Messenger SSG-II |
| Mr. P. Kamaraj | Mali SSG-II |
| Mr. V. Ganesan | Mali SSG-I |
| Mr. C. Kumaran | Mazdoor SSG-I (Superannuated on 31.12.10) |
| Mrs. K. Mariammal | Safaiwala SSG-I |

# 18 OTHER INFORMATIONS

## Hindi Day Celebrations

The Hindi Week was celebrated from 21st to 25th, September 2010 at this Centre. During the period, various competitions (essay writing, elocution, debate and cultural programmes like light music, jokes) were organized in Hindi and participants were encouraged to take part in the celebrations. The closing ceremony of the Hindi Day was held on 25th September 2010 in the Conference Hall. Shri. S. Dharmaraj, Airport Authority of India, Tiruchirappalli airport was the Chief Guest and Dr. M.M. Mustaffa, Director & Chairman, OLIC, NRCB presided over the function. In his speech, Sri. Dharmaraj, emphasized the importance of learning Hindi by every Indian citizen. Finally, the Chief Guest gave away the prizes to the winners of various competitions held in Hindi. In his address, he has highlighted the significance of Hindi knowledge and its usage in the day-to-day life. Practicing Hindi daily in the office works is very much important to spread the language rather than using it only during the celebrations. In the beginning, Dr. V. Pandey welcomed the gathering and presented the annual report to the forum and Dr. K.J. Jeyabaskaran proposed vote of thanks.

## NRCB Club day

The annual day of the NRCB Recreation Club was celebrated at NRCB on 28th August 2010. Sri V. Srinivasan, Station Director, All India Radio, Tiruchirapalli was the Chief Guest and Dr. M.M. Mustaffa, Director, NRCB presided over the function. The chief guest addressed the gathering to read more good books and follow it in the professional and personal carrier.

Finally, the Chief Guest distributed the prices to the winners of various sports and cultural activities. The staff members along with their family participated in the function.


# ANNEXURE - I

## List of On-going Institute Projects

### I. Crop Improvement

1. 2000711002 : Crop improvement of banana through conventional breeding
   **M.M.Mustaffa**
2. 2000711003 : Crop improvement of banana through non-conventional breeding
   **S.Uma**
3. 2000711004 : Improvement and management of banana genetic resources in Indian subcontinent
   **S.Uma**
4. 2000711005 : Identification and characterization of nematode resistance genes in banana
   **S.Backiyarani**
5. 2000711006 : Improvement of Rasthali through induced mutagenesis
   **M.S.Saraswathi**

### II. Crop production

6. 2000713001 : Standardization of agro-techniques for banana production and productivity
   **V. Kumar**
7. 2000713004 : Studies on micronutrients in banana
   **K.J. Jeyabaskaran**
8. 2000713006 : Fertilizer tailoring for targeted banana yield and sustainable soil health
   **K.J. Jeyabaskaran**
9. 2000716001 : Studies on physiology of flowering and fruit development in banana
   **I. Ravi**
10. 2000716002 : Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance
    **I. Ravi**
11. 2000716003 : Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance
    **I. Ravi**
12. 2000716004 : Physiological and biochemical mechanism of nematodes and pseudostem weevil resistance and identification of 'biomarker metabolites' in banana
    **M. Mayil Vaganan**

## III. Crop Protection

13. 2000715006 : Management of Banana weevils
**B. Padmanaban**

14. 2000715002 : Studies on banana nematodes and their management
**P. Sundararaju**

15. 2000715003 : Investigation on fungal and bacterial diseases of banana and their management
**R. Thangavelu**

16. 2000715005 : Studies on viral diseases of banana and their management
**R. Selvarajan**

17. 2000715007 : Host-virus interactions in Banana: Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's
**R. Selvarajan**

## ANNEXURE – II

### Meteorological Data

| Month | Max. Temp. (°C) | Min.Temp. (°C) | Relative Humidity (%) | Rain Fall (mm) |
|---|---|---|---|---|
| April 2010 | 27.26 | 38.83 | 84.53 | 63.30 |
| May 2010 | 26.90 | 37.93 | 85.25 | 129.79 |
| June 2010 | 26.73 | 37.13 | 82.03 | 10.14 |
| July 2010 | 26.19 | 35.48 | 80.58 | 35.88 |
| August 2010 | 26.25 | 35.67 | 80.32 | 81.30 |
| September 2010 | 25.09 | 34.46 | 84.76 | 64.68 |
| October 2010 | 25.80 | 34.19 | 88.38 | 49.44 |
| November 2010 | 24.13 | 30.10 | 93.86 | 248.20 |
| December 2010 | 22.35 | 28.96 | 92.45 | 62.74 |
| January 2011 | 21.38 | 30.54 | 90.54 | - |
| February 2011 | 21.96 | 33.25 | 90.00 | - |
| March 2011 | 23.83 | 36.45 | 88.03 | - |

# राष्ट्रीय केला अनुसंधान केंद्र

(भारतीय कृषि अनुसंधान परिषद)

तायनूर पोस्ट, तोगमलै रोड, तिरुच्चिराप्पल्ली - ६२० १०२, तमिल नाडु


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